No. 2.

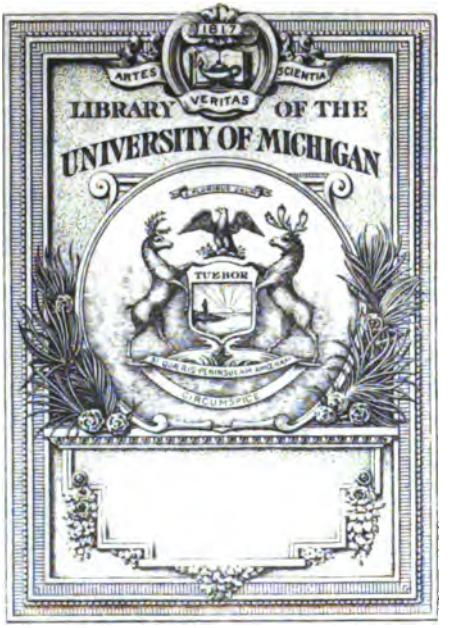
BULLETIN OF THE
UNIVERSITY OF KANSAS.

THE GREEN BUG AND ITS NATURAL ENEMIES.

RESULTS OF WORK OF THE UNIVERSITY OF KANSAS WITH THE COÖPERATION OF WHEAT GROWERS, MILLERS, AND GRAIN MEN OF KANSAS AND KANSAS CITY, MO., FOR THE YEARS 1907 AND 1908.

LAWRENCE, KANSAS.
1909.

ENTERED AT THE POST-OFFICE AS SECOND-CLASS MATTER.

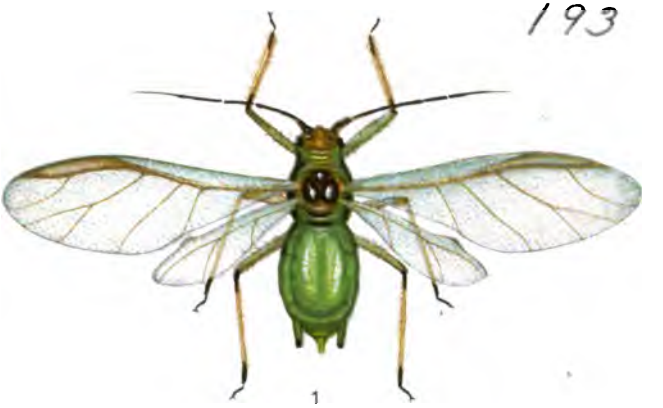

1817
ARTES
VERITAS
SCIENTIA
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
TUEBOR

THE "GREEN BUG," *Toxoptera graminum.*

FIG. 1. Migratory form.
FIG. 2. Wingless form.
FIG. 3. True female.
FIG. 4. Male.

PLATE I

193



1

2

3

4

SIBYL BETTS

A. HOEN & CO., BALTIMORE

VOL. IX. BULLETIN OF THE UNIVERSITY OF KANSAS. NO. 2.

The *Green Bug* and its Enemies.

A Study in Insect Parasitism.

By S. J. HUNTER,
Professor of Entomology in University of Kansas.

Influence of Climate on the Green Bug and its Parasite.

By P. A. GLENN,
Assistant Professor of Entomology in University of Kansas.

Department of Entomology, Contribution No. 137,
Issued October, 1909.

STATE PRINTING OFFICE,
TOPEKA, 1909.
2438

LETTER OF TRANSMITTAL.

Dr. Frank Strong, Chancellor of the University of Kansas:

SIR—I have the honor herewith to submit to you a special report on the Green Bug and its Natural Enemies, prepared by the professor of entomology and his assistants, with the coöperation of the wheat growers, millers and grain men of Kansas and Kansas City, Mo.

This report will form contribution No. 137 of the Department of Entomology of the University.

Respectfully submitted.

S. J HUNTER,
Professor of Entomology.

FOREWORD.

IN the spring of 1907 the green bug, a European insect inimical to growth of small grains, spread from Texas to Minnesota and from the Rocky Mountains eastward, making at this time its first recorded appearance in Kansas. In this state it spread rapidly, since it was unattended by its natural parasite. This afforded an excellent field for the study of the behavior of the host and its parasite by the introduction of the parasite.

The Department of Entomology of the University of Kansas, for this purpose, introduced the parasite at a number of points in the state. The practical and economic value of this work, as evinced by the experiments thus conducted, caused those interested in grain production to ask for an extension of this work and with funds to be furnished by these parties.

Accordingly, the following studies are the outgrowth of a limited series of experiments undertaken, first, by the University of Kansas, then enlarged and continued by the University at the request and with the hearty coöperation of the wheat-growers of Kansas and millers and grain men of Kansas and Kansas City, Mo. The following pages show, first, the practical results of this work carried on by the funds furnished by these interests, then the purely scientific results made possible by the University studies of this nature.

While this report covers only the years of 1907 and 1908, it is worthy of note that the 1909 outbreak of the green bug in Oklahoma served as a corroboration of the practical conclusions arrived at in this report.

For the benefit of those who have not time to read the full report, summaries have been arranged on pages 31, 161, and 180.

S. J. HUNTER.

UNIVERSITY OF KANSAS,
January 4, 1909.

CONTENTS.

ILLUSTRATIONS.

PLATES—LITHOGRAPH.

PLATES—HALF-TONE AND LINE.

TEXT FIGURES.

ACKNOWLEDGMENTS.

The three plates in color were prepared for lithographing by Miss Sibyl Betts.

Figure 11*a* and line plates I to V, inclusive, were prepared by Miss Sibyl Betts.

Plate 6 is from a chart prepared by P. A. Glenn, who also prepared the charts, figures 49 to 66, for his own article on climatic conditions.

Figures 1, 2, 6, 20, 21, 22, 24, 25, 26, 27*a*, 31, 40, 41, 42, 43*a*, and plates VIII and IX, are from photographs by P. A. Glenn.

Figures 3, 7, 8, 9, 10, 11, 16, 19, 23, 36 and 38 are from photographs by D. M. Horkman.

Figures 4, 5, 26*a*, 27, 28, 29, 30, 32, 34, 35, 37, 39, 43*b* and 48 are from drawings by Miss Hazel Branch.

Figure 33 is from a photograph by L. M. Peace.

Figures 44, 45, 46 and 47 are from drawings by Victor Chesky.

The series of experiments and the data recorded on forms of Toxoptera and origin and relation of the different forms were kept by P. A. Glenn, and the last two lines on page 107 should have appeared under this caption on page 108.

A STUDY IN INSECT PARASITISM.

THE insect commonly known as the "green bug" first came into prominence in 1852, at Bologna, Italy. Doctor Rondani, who described the species at that time, stated that in June the number of winged females was so great in all northern Italy as to form large groups like clouds in the air, causing great annoyance to the people, and later to cover the streets of the city with their remains. Since that year they have never been so overwhelmingly abundant in Italy, although the green bug has often been found sufficiently numerous in the regions of central and northern Italy to cause considerable damage to sorghum, corn and the small grains. It lives there on certain grasses of the meadows and pastures. In 1884 it became of economic importance in Hungary.

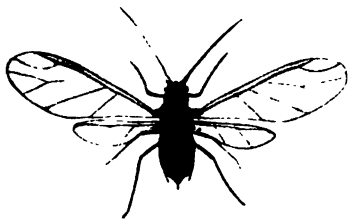


FIG. 1. *Toxoptera graminum*, migrating form; enlarged. From photograph. (Original.)

APPEARANCE IN THE UNITED STATES.

Since we are especially interested in its history and activity in the United States, it may be well to add with some detail that it was first recorded from the United States by the Department of Agriculture in 1882, locality not obtained. Two years later, however, it was found at Cabin John bridge, Maryland, causing considerable damage to wheat. The following year it was found at Oxford, Ind.; five years later, in 1890, on wheat at La Fayette, Ind., also in Posey county upon oats, in both places causing considerable damage to these crops. In this same year it was present in a large area of some of the grain-producing states of the South, being first reported from Monroe county, Tennessee. It destroyed much wheat in Alamance county, North Carolina, likewise in Cook county, Texas, where it is estimated that one-half the acreage was planted to other crops and the remaining half was about half a stand. Injury to oats was reported in June from Cadet, Mo. Beginning in March of the year 1901, and continuing through May, serious inury was reported to the Department of Agriculture throughout the grain belt of Texas. Thus far the most general occurrence was

the present year, where the green bug covered (approximately) in the United States the territory east of longitude 105. This, then, is its first known appearance in Kansas, and its behavior here becomes a matter of record for the first time.

Accordingly, since the subject of our discussion has to do largely with its presence in Kansas, a detailed statement concerning its activities elsewhere will not be necessary.

MODE OF LIVING.

Before taking up that phase of the subject it will be of interest to speak of its manner of life. This green bug is one of the plant-lice and is included in the same family as the "green fly" of the house and greenhouse plants and the "woolly aphis" of the apple. Its general structure groups it with the chinch-bug, the squash-bug, and the scale-insects. In common with all these it takes its nourishment, not by chewing the plant, as the grasshopper does, but by piercing the plant with a beak well adapted for drawing therefrom the plant juices. It is about one-sixteenth of an inch in length, pea-green in color, with a distinctly darker green stripe down its back. In common with other plant-lice, its different forms

FIG. 2. The "green bug." *Toxptera graminum*. The pupa, the form which develops into the winged migrant. Greatly enlarged. From photograph. (Original.)

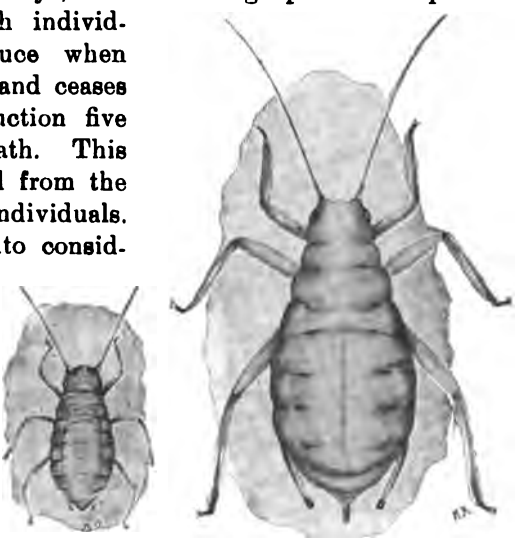
FIG. 3. *Toxoptera graminum*, oviparous female and egg on wheat leaf. From photographs retouched; enlarged. (Original.)

and the ways in which these forms appear are of almost magic interest. In its economy it plans to spend the winter as an egg.

These eggs are deposited early in the fall by true females on the leaves of the host-plant. Out of these eggs in the early spring hatch the form known as the "stem mother." Judging from other species, it is probable that these stem mothers are wingless and reproduce without fertilization. The offspring of these stem mothers may be either winged or wingless, and they in turn reproduce without fertilization. Throughout the whole summer season there are no males nor true females, but each and every individual gives birth to young, at the rate of about two per day, during the greater part of the life of each individual.

LENGTH OF LIFE AND NUMBER OF OFFSPRING.

In our experimental laboratory, from May to September, the average life is thirty-six days, and the average production per individual fifty-six. Each individual begins to reproduce when about seven days old and ceases the process of reproduction five to ten days before death. This is an average computed from the life-record of many individuals. Now, when you take into consideration that there are no sterile individuals among these summer green bugs —that each and every one of the offspring begins to repeat the series of reproductions when seven days old, and that the offspring are born and do not have to await the slower process of hatching from an egg, as do most other insects, you can understand, in a measure, how these insects can appear in such countless numbers in a time so short as to be almost incredible.



a *b*

FIG. 4. *Toxoptera graminum*. *a*, newly born, and *b*, adult wingless "green bug," greatly enlarged. (Original.)

Its rate of growth and reproduction is obviously very much slower at this season of the year (January). The subject of temperature in relation to the green bug is an important one, and our studies upon that phase are not yet completed. Suffice it to say,

that in such weather as we have had during the month of December the green bug requires from thirty to sixty days to reach maturity. Even development in the laboratory requires three times as long as it did in the summer months.

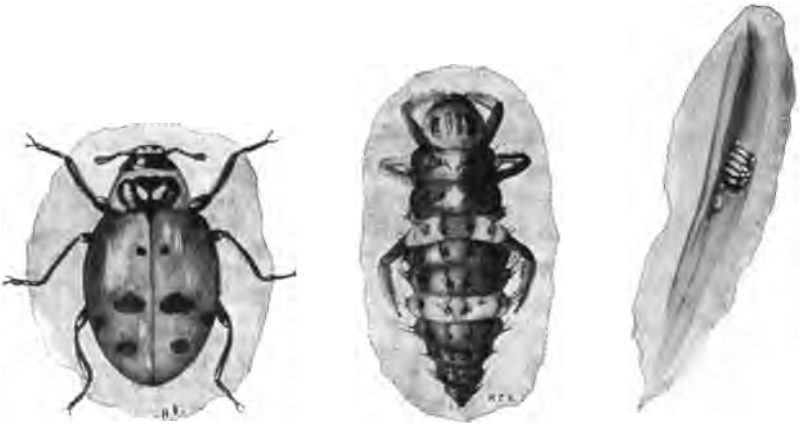
SPREAD OF SPECIES.

Now, were all these forms wingless the economic problem would be greatly simplified. On the contrary, however, many of these agamic green bugs become winged and fly to other fields, there to found new colonies which establish new series of agamic generations. Thus the spring and early summer is spent, subsisting principally upon wheat, oats and other small grains, until these plants have become too mature for succulent nourishment. Then, if need be, the green bug can tide over the brief period between reaping and sowing on certain grasses of the meadows and pastures. This inconvenience has not been caused them, however, this year, as our field observations have uniformly shown that they have taken advantage of the volunteer grains, allowed to stand by the farmer, unmindful of his own interest, at this critical and vulnerable period in the life of this thrifty insect. Volunteer grains have long ferried the Hessian fly over the perilous period in its life journey, and it seems now that the green bug is using the same material for the same purpose.

FOOD PLANTS.

The tastes of the green bug include a rather wide range of plants. With us it has prospered on wheat, oats, rye, barley, spelt, corn and a number of the grasses. It is also recorded on sorghum. So you see this shifty species is not likely to want for food. Adaptability, and ability to subsist on such a large range of food plants, is no small factor in its successful existence.

In this way the green bug spends the summer, subsisting, growing, producing, reproducing, generation after generation, in successions of seven days. We have computed the progeny of one individual. Doctor Forbes has made an estimate of the rate of increase for the corn-root aphis, a member of the same family as the green bug, which goes to illustrate its fecundity. A single stem mother of the corn-root aphis has from twelve to fifteen offspring, which mature in a fortnight. "Supposing," says Doctor Forbes, "that all the plant-lice descending from a single female hatched from the egg in spring were to live and reproduce throughout the year, we should have coming from the egg the following spring nine and a half trillion young. As each plant-louse measures 1.4 mm. (1-16th in.) in length and 0.93 mm. (1-32d in.) in



a *b* *c*

FIG. 5. *Hippodamia convergens*, a ladybug which devours the "green bug." *a*, adult; *b*, larva; *c*, cluster of eggs. (Original.)

width, an easy calculation shows that these conceivably possible descendants of a single female would, if closely placed end to end, form a procession seven million eight hundred and fifty thousand miles in length; or they would make a belt or strip ten feet wide and two hundred and thirty miles long."

Returning now to the green bug, these agamic individuals in the fall give birth to true males and females, and these true females lay truly fertilized eggs, out of which the following spring will come the stem mothers, to continue the production of the agamic generations.

INSECT ENEMIES.

Predaceous.—The life of the green bug, however, is not all clear sailing. There are certain other insects which subsist largely upon

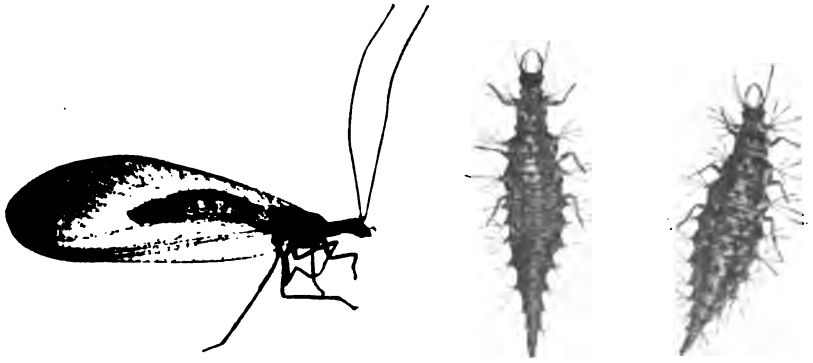


FIG. 6. *Chrysopa* sp. Lace-wing fly and larvæ. Greatly enlarged. From photograph. (Original.)

it, devouring great numbers. Chief among these predaceous forms may be classed the "ladybugs," little red, spotted beetles, common in the grain-fields. These are well known in the adult stage, but the immature, dark, spotted, slug-like, voracious grubs from which they develop are not so well known. These little slug-like, immature forms were frequently sent to the department last summer, accompanied by the information that they were causing the injury to the wheat. On the contrary, they were an active agency in reducing the number of green bugs. One of these by actual count will eat from thirty to one hundred green bugs a day. The clusters

FIG. 7. Cluster of eggs of lace-wing fly, slightly enlarged. From photograph. (Original.)

of orange-yellow eggs of the ladybug, from which these slugs hatch, you have no doubt seen attached to leaves of the wheat.

In this predaceous class comes the immature stage of a wonderfully delicate, green, gauzy-winged insect called the lace-winged fly. The immature or developing stage of this beautiful insect is a fiercely predaceous creature, called an "aphis lion," because it crawls about over the plants in search of such plant-lice as the green bug, piercing its prey with its long jaws and sucking the blood of its victims.

Another is a small, slender, greenish maggot, the offspring of a rather brightly banded fly, which subsists in its immature stage on plant-lice such as the green bug.

Parasitic.—More potent, however, in decimating the ranks of

the green bug are the parasitic insects, those whose young spend the developing stages in the bodies of plant-lice.

Chief among these parasites is the one which was so active last spring (1907), and to whose activity is due the control of this harmful insect. This parasite is a small, black, wasp-like creature, a little longer than the green bug but not so large in body. The female parasite can be seen by an ordinary observer, running up and down the leaves of the plant in quest of green bugs upon which to lay her eggs. As soon as she perceives one with her feelers, she quickly thrusts her abdomen out from under and in front of the head until the tip touches the body of the green bug. In this way the egg is laid in the body of the green bug. She repeats this process in quick succession upon a number of green bugs, then rests and cleans her feelers, ready to repeat the operation. In about twenty-four hours of the summer season the body of the newly parasitized green bug begins to turn an orange-yellow, and usually before the third day it is dead, much swollen, and securely fastened to the blades by the internal parasite.

FIG. 8. Cocoons and eggs of lace-wing fly, about natural size. From photograph. (Original.)

Out of this shell, about four days later, another little wasp-like parasite emerges to repeat the process of parasitizing other green bugs. In this manner countless numbers of green bugs are soon changed from active, plant-destroying insects to harmless dead insects, out of which come crop protectors.

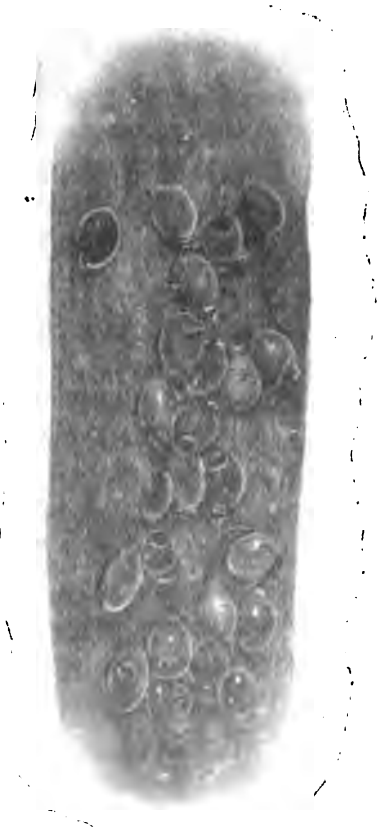
The parasitic insect lives only on other insects, and under no manner of necessity could it reproduce on plant life. Accordingly it could never become a menace to growing crops of any kind.

That this parasite not only controlled, but in many places practically exterminated, the green bug last season, no one questions. The work of the parasite was made known, not by the absence of the green bug, but by the countless numbers of dead bugs clustered on the blades of grain, unimpeachable witnesses of the effect of this parasite.

The Parasite and the Green Bug.

Now the question naturally arises, with such an enemy as this

9



10

FIGS. 9 and 10. Parasitized "green bugs." The parasites have emerged in some instances. Enlarged from photograph. (Original.)

parasite proves to be, why does the green bug flourish at all? In reply, it may be said: In the first place the green bug continues to be active and reproductive at a lower temperature than does this parasite. No one acquainted with the facts questions this. And so we find the green bug reproducing, even at this late date in the year, many winged migrants, which are founding new colonies in new localities, while the parasite is almost inactive. Furthermore, an examination of the structure of the two insects shows a much larger wing expanse in the green bug, suited to soaring and ready transportation by the wind. Taking into consideration the relative weights of the bodies of the two insects, the green bug still has an advantage in the matter of its flight and ability to be carried for long distances through the air. Futhermore, the instinct of this migrant is to take to the wind to migrate.

FIG. 11. The upper figure is a photograph of the winged migrant, the lower of the parasite. Photographed on same scale to show advantage possessed by migrant in the matter of wing expanse.

As for the parasite, its wings have less than half the surface area and flight is attained largely by muscular vibration; that is, it works its way, while the green bug simply holds itself in the air and depends largely on the wind for transportation. The parasite is content to remain in a place as long as there are green bugs upon which it may oviposit.

It has been stated that there is a possibility of the parasite being transported as an egg in the body of the winged migrant. Were this the case, we would then expect it to accompany the green bug, and to be present wherever the green bug is. Since this possible means of the transportation of the parasite is merely an hypothesis, we will have to look for its verification in conditions as they exist.

And here we must deviate and enter somewhat into the development of the experimental phase of this subject during the past season (1907) in Kansas.

DEVELOPMENT OF EXPERIMENTAL WORK.

On March 9, 1907, the following telegram was sent: "*C. E. Sanborn, College Station, Tex.*—Wire name of insect damaging wheat in Texas. State amount of damage.—S. J. HUNTER." The answer was: "*College Station, Tex.*, March 10. *S. J. Hunter, Lawrence, Kan.*—*Toxoptera graminum.* Damage, fifty million bushels grain.

It was present in Kansas December, naught six. I am working on it. No good remedy yet.—C. E. SANBORN."

On March 26, letters were sent out to correspondents in the principal wheat-growing sections of the state, asking that wheat be examined, and if insects of any kind be found therein that boxes of wheat so infested be sent to this department at once. This resulted in wheat being received from twenty-seven localities up to April 16, as shown in map I, all of which revealed the presence of *Toxoptera graminum*, commonly known as the green bug, but nowhere was the principal parasitic enemy found.

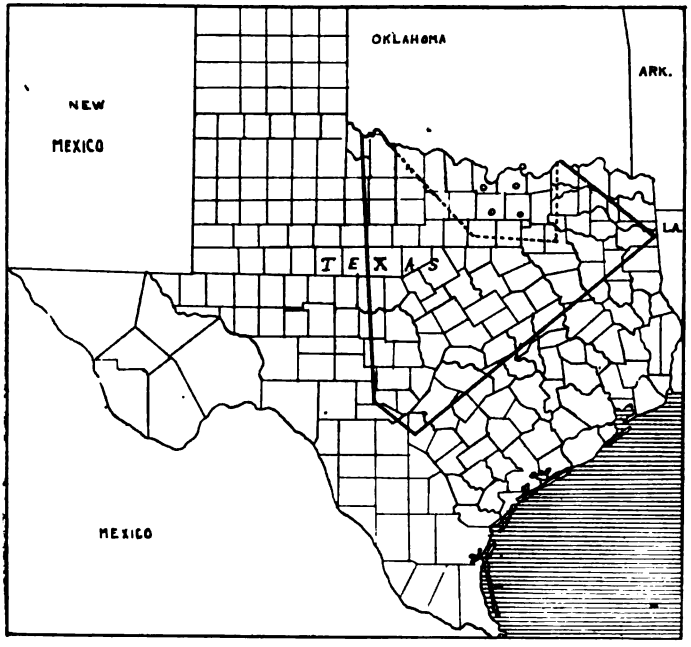


FIG. 11a. Map of Texas showing area of original outbreak of "green bug." Double line shows area of infestation; dotted line shows area of greatest infestation; ○ ○ ○ ○ points where outbreak of "green bug" originated. (After Sanborn.)

ASSURANCES.

In answer to these correspondents and to many other inquiries, the assurance was given that serious injury would not be wrought in Kansas by this insect. An example of many letters is the following:

"*Mr. C. A. Kirkendall, Emporia, Kan.:* APRIL, 9, 1907.

"I have your courteous letter of the 7th inst. The article referred to by you was written and published without my knowledge or consent. Accordingly, as might be expected, it has some mis-

statements. In the first place, the insect there named is not the one creating the most damage in the wheat of the South; in the second place, the department is not endeavoring to distribute the predaceous or parasitic enemies of the "green bug," known to science as *Toxoptera graminum*, for the reason that our observations show that these enemies of this pest follow it up faster than we could distribute the parasites. You will doubtless observe them in your field—a little black four-winged fly, a number of small spotted beetles, and probably one or two species of larger, green gauzy-winged insects. S. J. HUNTER."

CONDITIONS RENDERED ASSURANCES GROUNDLESS.

This was my own opinion, and I based these assurances upon experience with the European grain-louse, *Siphocoryne avenæ*, in Kansas in 1901. The green bug, however, is a hardier, more active, more prolific species.

When, then, on the 14th of April, it was evident from reliable sources, viz., the packages of infested wheat referred to,① and re-

---

NOTE 1.—List of persons sending package of wheat infested with *Toxoptera graminum*, "green bug," with date of sending, up to and including April 18:

1. Geo. W. Lemon, president Bank of Pratt, Pratt. April 2.
2. Geo. H. Hunter, Wellington. April 3.
3. J. C. Hines, Haviland. April 6.
4. J. M. Lane (Lane & Kent), Burlington. April 8.
5. M. H. Cox, county commissioner, Fredonia. April 8.*
6. Ernest Christenson, Cabbell. April 9.
7. H. V. Williams, South Haven. April 9.
8. Alexander Anderson, Winfield, R. F. D. No. 10. April 10.
9. A. H. Tomlin, Oxford, R. F. D. No. 3. April 10.
10. Chauncey Vaniman, cashier People's State Bank, McPherson. April 10.
11. John A. Henning, M. D., Ph. D., Garnett. April 12.
12. John A. Devlin, Iola. April 13.
13. E. Livingstone, St. John. April 13.
14. D. W. Roush, Preston. April 13.
15. A. T. Ballard, Colony. April 15.†
16. J. A. Fix, Fredonia. April 14.
17. W. E. Callaway, Medicine Lodge. April 15.
18. W. A. Dawson, Iola. April 15.
19. Robert J. Shearer, Lewis. April 15.
20. Harry E. Kiff, Abilene. April 15.
21. D. W. Matxler, Humboldt. April 16.
22. Nell V. Pyle, Haviland. April 17.
23. John Schoenhofer, St. Paul. April 17.
24. W. E. Cox, Healy. April 18.
25. C. J. Hammer, Ellinwood. April 18.
26. Paul Jones, Chetopa. April 9.
27. C. H. Ansemus, Cherokee. April 18; or,
28. Alfred Rush, Cherokee.

---

* A second package came from M. H. Cox on April 28.

† Package received on April 17 contained the only parasites received from any location in the state up to this date.

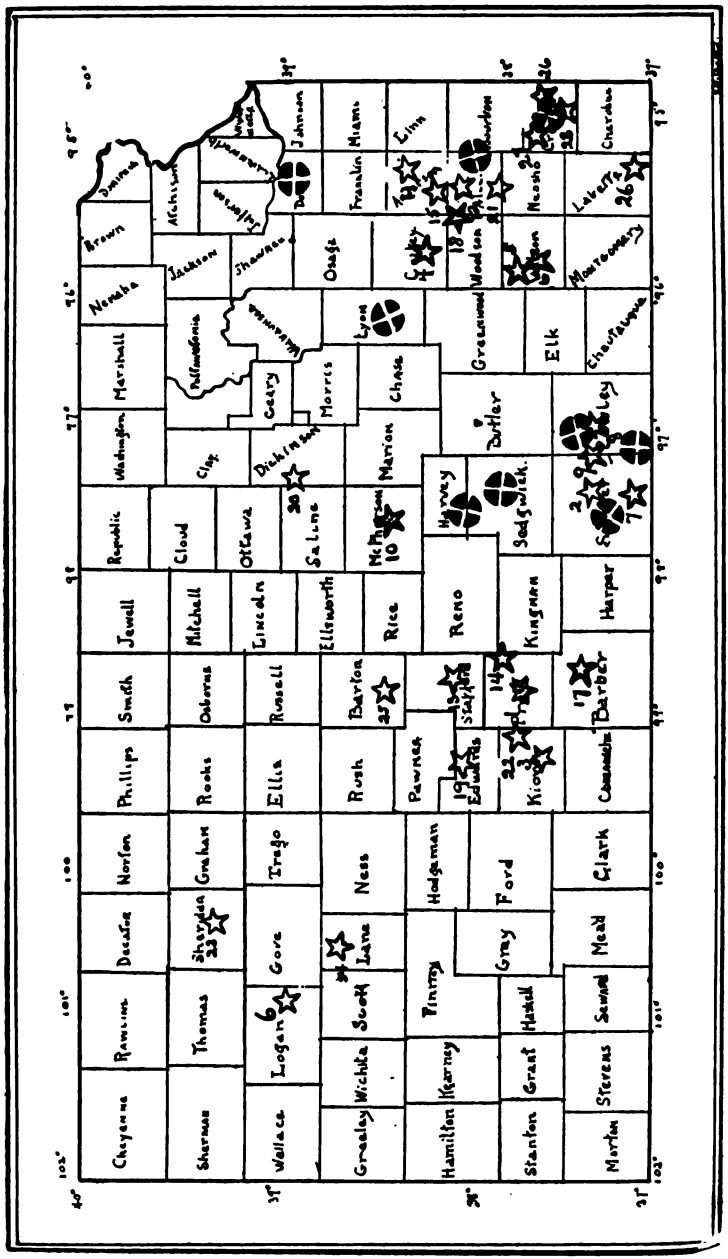


PLATE I. MAP I. KANSAS. The stars show localities from which packages of wheat infested by *Tozoptera graminum* (commonly called green bug) were received. No parasites contained in these packages. Numbers to the left of stars give date in April when received. The crosses in black circles mark localities examined between March 29 and April 14, by C. E. Sanborn, agent of United States Bureau of Entomology, detailed at request of Texas millers to study conditions in Kansas. In these places he found green bugs plentiful, but no parasites, except at one point five miles north of Arkansas City. Dates to left of black circle.

ports[2], after personal examination, of Agent Sanborn, of the Federal Bureau of Entomology, of areas shown in accompanying chart (map I) that the green bug was present throughout the wheat area of the state, and the principal natural enemy, the parasite, was not found anywhere in the state except at one point on the extreme southern border; that the weather conditions were such as to hinder, if not preclude, its wide distribution naturally, it seemed but reasonable and entirely fitting that this parasitic insect inimical to the increase of the green bug should be as widely distributed as possible; the more so when urgent requests were being received by letter, telephone and telegram from wheat raisers, millers and grain men asking that something be done.

APPROPRIATION BY THE UNIVERSITY.

Accordingly the matter was presented to Chancellor Strong, and $150 was appropriated for the work. This amount gave an opportunity for a practical test by those most interested, so that in a large measure this initial sum was responsible for the subsequent scope of the work.

COÖPERATORS.

Field-station, Enid, Okla.[3]—Mr. C. E. Sanborn, an agent of

NOTE 2.—JULY 12, 1907.

Prof. S. J. Hunter: DEAR SIR—Following is a brief summary of the green bug observations, taken from my notes, made in Kansas:

March 29, examined wheat and oats fields west of Arkansas City. The green bug was universally present, but there were no parasites.

April 3, examined wheat and oats fields in vicinity of Wellington. Found the green bug universally present, but there were no parasites.

April 5, examined wheat and oats fields at Winfield and again at Arkansas City. In the latter place parasites were beginning to appear, but there were none at Winfield. Green bugs were universally present at both places.

April 6, arrived at Wichita. Conditions were similar to Winfield.

April 7, examined wheat and oats fields all around Halstead. The green bug was universally present, but there were no parasites.

April 7, found green bugs plentiful at Emporia, but there were no parasites.

April 8–12, found conditions similar at Lawrence, except that there were fewer of green bugs. Numerous packages examined in the Kansas University state entomological office were found to contain no parasites. Every package contained green bugs, which were in thoroughly healthy condition as far as parasitism was concerned.

April 13, examined wheat and oats fields at Moran. The green bug was universal y present, but there were no parasites.

April 14, examined wheat and oats fields at Girard. Found green bugs universally present, but there were no parasites.

The most northern point at which any parasite was observed by me was five miles north of Arkansas City. This was on the 5th day of April. Furthermore, during my itinerance in Kansas the weather was too cool for any general dissemination of parasites. This cool weather continued for several days after I left Kansas. Very truly yours,

(Signed) C. E. SANBORN,

In Charge of Green Bug Investigations in Texas.

the Federal Bureau of Entomology, who at that time was in Kansas, detailed by the Texas Agricultural College, at request of the Texas grain dealers, to study the green bug situation, kindly offered to report a favorable location from which to distribute the parasites. On his return trip through Oklahoma he decided upon Enid. Messrs. W. S. Griesa and E. S. Crumb, students in the department, arrived at Enid on the 16th of April and began sending out parasites on the 17th. For over two weeks they conducted the work here without recompense other than actual expenses. At the end of their stay Messrs. Harold Armsby, Maurice Breidenthal and Victor Chesky took their places upon the same terms, for the same length of time. Messrs. Griesa, Crumb and Chesky rendered valuable services throughout the work—the first in charge of shipments from Lawrence, the second in the field, and the third in the laboratory.

Field-station at Peabody.—Through the active coöperation and direction of Hon. T. M. Potter, a field-station was established on May 20 at Peabody, and shipments made from there. Prof. P. A. Glenn, then of Highland College and to be acting head of the department of entomology for the coming year at the University of Missouri, came to the work here, making field observations after shipments had closed.[3]

NOTE 3.—Since this introductory general statement is for the purpose of giving the facts in the case as well as the connections of all participants, it would not be complete did it not include reference to the Bureau of Entomology of the United States Department of Agriculture.

On May 13 the following telegram was received:

"WASHINGTON, D. C., May 13.

"*Prof. S. J. Hunter, University of Kansas, Lawrence, Kan.:*

"Senator Curtis brings report of your work with parasites against green bug. Please wire for information Secretary of Agriculture, name of parasite and full statement of present conditions and what you have accomplished. (Signed) C. L. MARLATT."

And this was the reply:

"LAWRENCE, KAN., May 13, 1907.

"*C. L. Marlatt, Bureau of Entomology, Washington, D. C.:*

"Distributed 2000 boxes of *Lysiphlebus* over Kansas. Results uniformly satisfactory where parasites introduced. Limited funds curtailed much desired expediency and larger working force. Strong southerly winds cause general distribution of *Toxoptera* over state. Damage to small grain confined to a few southern counties. Great need for large funds to make work comprehensive, thorough, conclusive. (Signed) S. J. HUNTER."

The answer was:

"WASHINGTON, D. C., May 14, 1907.

"*S. J. Hunter, University of Kansas, Lawrence, Kan.:*

"Telegram from Ainslie to-day says fifty per cent. *Toxoptera* in southern Kansas now parasitized. Parasitized aphis abundant in every field since last Saturday. Adult parasites emerging in increasing numbers and now actively at work. With favorable weather parasites should destroy remain-

The fund appropriated by the University was before this time expended, and the work would have been suspended had Mr. R. C. Jackman, manager of the Bowersock Mill and Power Company, not taken the financial part of the work in hand. He first presented the situation to Hon. J. D. Bowersock, who at once sent $100 as a guarantee fund, with the assurance of more if necessary. How well Mr. Jackman carried out his part of the work is best shown by the list of names, resulting in $2316.39 being received. A part came too late to be of service this year and so was returned, the guarantors receiving 53½ per cent. of their guarantee.

The Bell Telephone Company gave unlimited service over its whole system, an invaluable aid, enabling the department to keep in direct and satisfactory communication with all field work.

The Wells-Fargo, the Pacific, the United States, the Adams and the American express companies transporated all packages free of charge within the state. In the beginning the boxes of parasites were sent by mail at cost of twenty-four to thirty cents per box. Over 8500 were transported by these express companies. Transcripts from the companies' books show total amount of business handled without charge, $2847.30; express on bulk material from Enid, $215.65.[4]

---

ing green bugs here before end of week. Webster despatched to Kansas to look over the ground and will see you in Lawrence.

(Signed) MARLATT."

Webster came to Kansas but did not come to Lawrence, and this was unfortunate, for we were thus deprived of the counsel of the Bureau of Entomology; and the only published information concerning this work of University that was transmitted by this agent to the Bureau of Entomology was the indefinite and inadequate statement that: "During the last two weeks of April a great many small lots of parasites were distributed over the southern and central counties of Kansas."*

* U. S. Dept. Agr., Bureau of Entomology, circular No. 93, p. 10.

NOTE 4.

Prof. S. J. Hunter, Department of Entomology, University of Kansas:

DEAR SIR—Please find herewith statement of the number of packages handled by Wells-Fargo & Co. and the Pacific Express Company free of all charges to the farmers of Kansas in their efforts to kill the green bugs in Kansas during the months of April, May and June, 1907:

Wells-Fargo & Co. Express handled 2971 packages parasites at 25 cents	$742 75
Wells-Fargo & Co. Express handled 890 empty boxes and return at 25 cents each	222 50
Wells-Fargo & Co. Express handled raw material from all points,	493 65
Total	$1,468 90
Pacific Express Company handled 2685 packages parasites at 25 cents each	$671 25
Pacific Express Company handled 671 return empty boxes at 25 cents each.	167 75
Total	$839 00

(over.)

This work of combating the green bug received much more publicity than usual now with University investigations of this nature. Those directly in charge of the financial part felt that the needs of the time demanded that the public be kept fully informed in order that funds might be forthcoming. That is, had the University had money sufficient to have carried on the work on a scale commensurate with the demands, it would have done so in its own way.

GREEN BUG UNACCOMPANIED BY PARASITE.

Reference to map I, in which twenty-eight localities are marked, with accompanying dates, shows from whence packages of wheat infested by green bugs had been received. The number of green bugs in these packages ranged from 100 or so to several thousands. In none of these save one was there any evidence of the presence or work of the parasite. This exception, collected on the 14th and received on the 17th of April, has an important bearing. The box was 3½x2x1 inches in size, and contained about 100 green bugs, about one-fourth of which were parasitized. Some of the parasites had emerged in transit, so that it is quite probable that a number of green bugs were parasitized after being placed in the box. This box came three days after the work of distributing the parasites had been set in motion at Enid, Okla. This box was evidence that the parasite would work, if present at this date, in Kansas; and that they could be received, if collected and sent in packages, by the wheat growers.

Examination of the map Fig. 12, shows that the territory covered by the parasite, representatives of which were received in this box from Mr. A. T. Ballard, near Colony, Kan., was by no means general, for Doctor Henning, of Garnett, fourteen miles northeast in the same county, collected and sent infested wheat on the 12th; John A. Devlin on April 13, and W. A. Dawson on the 15th, both of Iola, each farm about ten miles south of Colony; and D. W.

Wells-Fargo & Co. Express and the Pacific Express Company handled for points located on the lines of the United States Express Company, Adams Express Company and American Express Company a total of 1535 packages of parasites at 25 cents each	$383 75
Empty packages returned from these points	67 75
Total	$451 40

Grand total free business handled from Lawrence, $2,759.40.

Wells-Fargo handled from Peabody raw material free to the amount of $87.90.

Wells-Fargo handled raw material from Enid, Okla., to points in Kansas to the amount of $215.65. I am, very truly yours,

A. R. MAXWELL,
Agent Wells-Fargo and Pacific Exp. Cos.

Matzler, of Humboldt, seven miles south of Iola, sent on the 16th of April, green bugs, all of which were free from parasites. Then, referring to Sanborn's field-notes: "April 13, examined wheat and oats fields at Moran. The green bug was universally present but there were no parasites." Moran is twelve miles east of Iola and fourteen miles southeast of Colony. Here, then, are a series of observations within a period of two days, from six localities, within the area of an obtuse angle whose base is thirty-one miles and whose altitude is ten miles, in only one of which was the parasite found, and this the only place in the state.

That is, packages of wheat were examined from twenty-eight widely separated localities, the most northerly, Sheridan county, being about 154 miles from the southern part of the state, and the most westerly, Logan county, 322 miles from the eastern part of the state; and Sanborn's examination of nine different vicinities in as many counties, revealing the presence of green bugs in all of this territory, but the existence of the parasite in only two, would seem to be conclusive evidence that the parasite is not to be found wherever the green bug exists.

Another and more notable illustration of this fact is to be found in the report of Mr. F. M. Webster:[1] "The quite serious outbreak of the green bug is at present (July 25, 1907) in progress on the grounds of this department at Washington, and chiefly on blue-grass. . . . and especially is it notable in view of the total lack of *Lysiphlebus tritici*, the most important of the natural enemies of this aphis." Mr. E. O. G. Kelly, who was in charge of the insecticide work against the green bug on these grounds up to July 31, stated to the writer that even at the time when he left no *Lysiphlebus tritici* could be found there.

Here we have a condition which would seem to be in every respect ideal for the free natural distribution of the parasite—a period preceded by several months of warm southern weather, ample opportunity, it would seem, for the parasite to have been introduced either by flight or carried as an egg in the body of the winged migrant; and yet the countless numbers of green bugs did not attract or bring with them a single parasite.

REPRESENTATIVE FIELD EXPERIMENT.

In Douglas county, where conditions by reason of proximity were closely watched, the accompanying diagram (fig. 13) illustrates one series of observations. *A* is a sixty-acre field of wheat which belonged to Mr. Charles Wall; *B* a thirty-acre piece, the property

1. U. S. Bureau of Ent., Cir. No. 93, p. 5.

of Mr. M. O. Adams. On April 25, noon, Messrs. Adams and Wall distributed under direction a box of parasites in each of these fields. No parasites had previously been found here, nor evidences of their work. The wheat in Mr. Adams's plot was short and thin upon the ground, so that careful observations, rod by rod, could be made. The number of green bugs averaged about one to the plant throughout the field. Colonies of as many as seven were to be found on some blades. On the afternoon of April 28, Mr. Adams, Mr. Griesa and the writer went over this field and found everywhere newly parasitized green bugs, ranging in stages from the early indistinct orange-tinged abdomen to the brown dead body of the green bug. (The temperatures from April 20 to April 28 were, maximum and

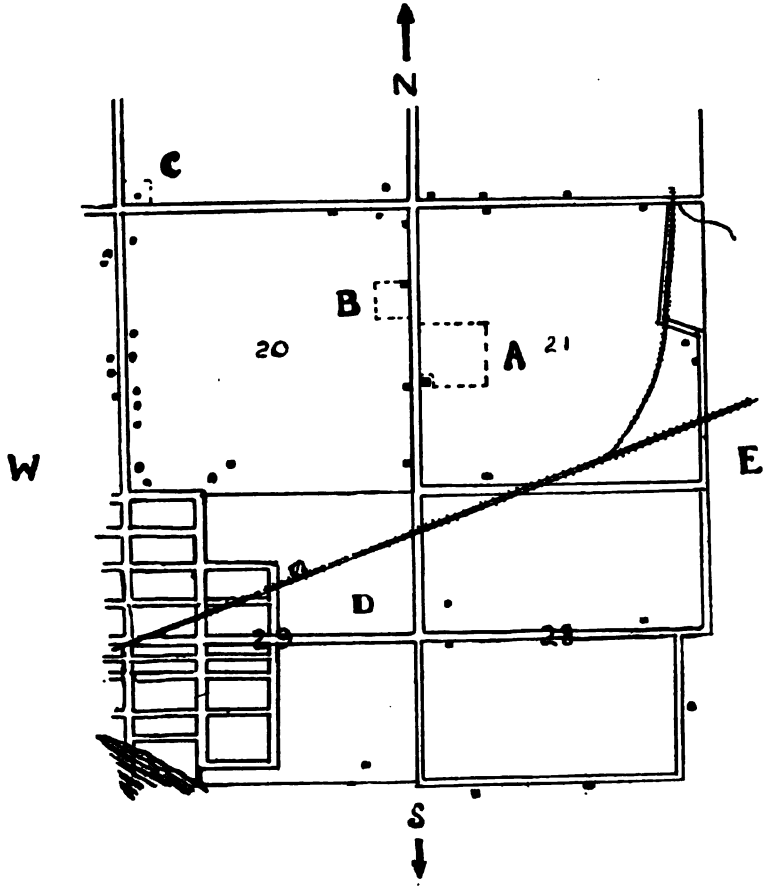


FIG. 13. Diagram of one field experiment. Parasites distributed at *A* and *B* on April 25. No evidence of parasites previously found in this vicinity. Parasitized green bugs found there on 28th. On same date parasites found at *C* but no parasitized green bugs. May 1 green bugs examined at *D*. No evidence of parasites.

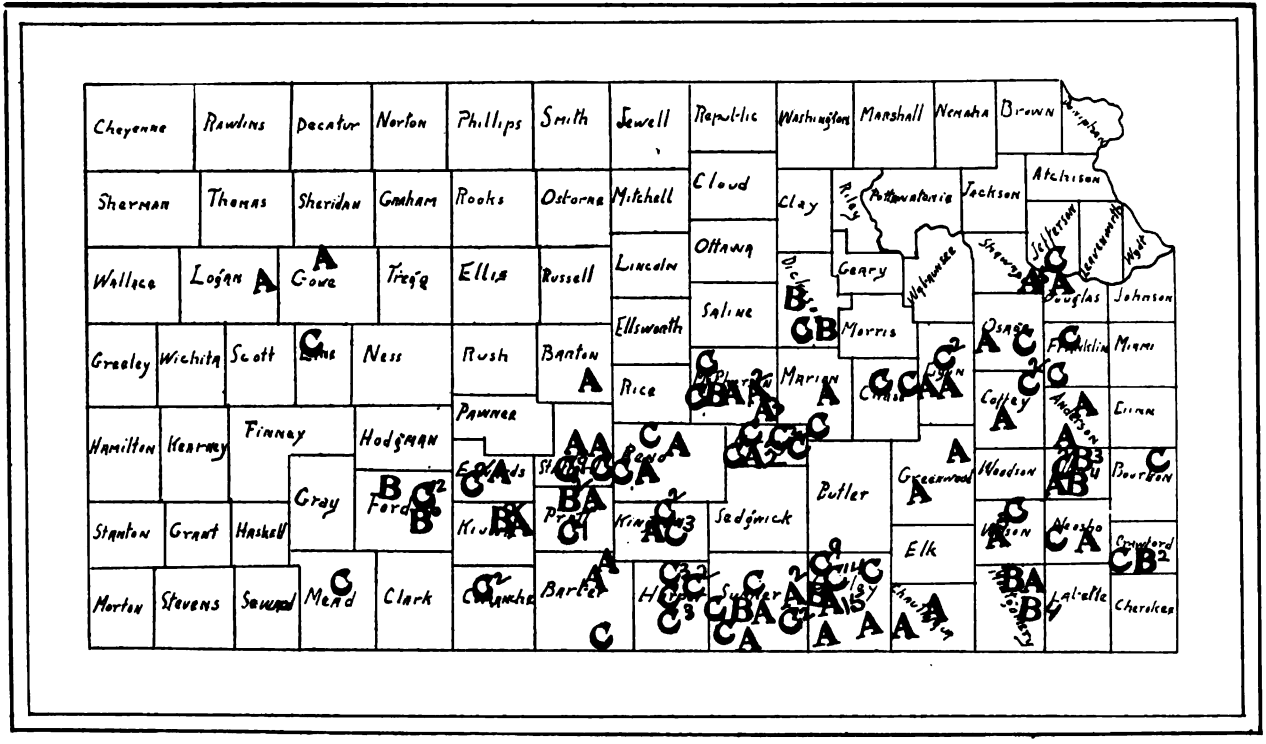


PLATE II. MAP II. KANSAS. *A*—Localities in which parasites were distributed April 18, total 59.
B— " " " " " " 19, " 31.
C— " " " " " " 20, " 106.
Numbers to right of letters denote number of packages sent to that locality.

minimum, respectively, 54, 35; 60, 34; 64, 42; 75, 42; 81.5, 49; 49, 38.5; 63, 32.5; 75, 48.5; 69.5, 45.5—temperatures at which the parasite would have worked had it been present previously.) The mean temperature for April 20 to 25 was 53.84, and for April 25 to April 28 the mean temperature was 51.86, showing more favorable temperatures for the five days previous to the introduction, and thus the greater probability of activity of parasites, if such had been there. Parasites were actively at work. The smallest number counted on any square rod was six. While the observers were watching three green bugs on a blade, two parasites ascended the blade, one oviposited on one of the green bugs, the other on two of them.

Now, if parasites had been here previous to the artificial introduction, unnoticed, later stages in their life-histroy would have been found. The last rainfall, 0.07 of an inch, was on the 18th, so that parasitized bugs could not have been washed off. And, as it was, not a single parasitized green bug was found out of which the parasites had emerged.

C represents twelve acres of wheat, examined on the afternoon of April 28 by Mr. Griesa and myself. Green bugs were present about one to every fourth plant. The parasites were found along the west line of the field, but no parasitized green bugs were found. On the afternoon of May 1, the plot of ground in wheat south of railroad, at *D*, was examined. Green bugs were present but no parasites were found. The natural conclusion is that no parasites were found but those introduced, and that those in the field at *C* had come from the fields *A* and *B*, since they had not been there long enough to show any effect on the green bug. May 12 Mr. Jackman, Mr. Adams and I examined the field at *B* and could find very few living green bugs. Parasitized green bugs and adult parasites could be readily found. The same was true for the field at *A*. Here, however, there were some of our common European grain-louse, in this field at *A*.

This experiment is given as one of those illustrating the fact that to be most effective the parasites must be introduced early. Thus they not only check the increase of the first colonies but from them obtain reinforcements to wage war on incoming green bugs. In other words, artificial introduction is not a remedy but a preventive.

Now let us turn to map III, which considers the state as a whole and records the dates and localities studied by four observers. Briefly, all observers, during the last week of May and the first week of June, report that in central and southern Kansas parasit-

ized] bugs were abundant, living green bugs few, adult parasites plentiful.

EXTRACTS FROM NOTES.

(Hunter's trip looking for favorable location from which to distribute.)

May 19.—Drove two miles east, one mile south of Caldwell. Examined six wheat-fields, one oat-field; shells (dead bodies of green bugs from which parasites had emerged) abundant. Parasites emerging from bodies of green bugs in such large numbers as to make export impractical. The most southern fields had, according to owner, millions of green bugs one week before Wheat beginning to head out. Green bugs nearly all parasitized. A few living ones on upper leaves. Saw ladybug larva devouring adult *Toxoptera*. This field, contrary to a notion prevalent that on account of toughening of stalk green bugs leave wheat as soon as it begins to head, showed the bugs feeding on heading plants, and in some cases on upper leaves.* Mr. E. W. Melvin, Rock Island engineer, was with me. Heavy shower at 11:40. Came up in afternoon to Wellington. Was driven out over territory north and east of Wellington by G. H. Hunter, president of Milling Company, and his son-in-law, Mr. Voile. Conditions much the same as at Caldwell.

May 20.—Reached Peabody at noon. After lunch was driven out over country east by Mr. T. M. Potter. First field, one mile east, was well stocked with green bugs, most of which were parasitized. Returned to town, secured four boys, and in two hours collected and packed two boxes. Shipped to Lawrence.

May 21.—With four boys collected and shipped eight boxes to Lawrence, and Crumb came at noon.

May 28.—Drove from McFarland to Alma, returning by another route. A few shells found on wheat-stalks; many shells found on oats. No living green bugs seen. Met Glenn and Crumb at Herington. Glenn left for Trego county; Crumb and I returned to Lawrence without finding green bugs anywhere to be used for propagation and distribution of parasites.

GLENN'S FIELD OBSERVATIONS.

On May 28, while on my way to Collyer, Kan., to inspect the green bug situation in that locality, I was obliged to wait in Abilene three hours for my train. While waiting I visited an oats-field about one-half mile northeast from the Union Pacific station, and found it badly infested with green bugs. The most of them, however, were dead, having been stung by the green bug parasite.

May 29 I drove from Wa Keeney to Collyer, in Trego county, a distance of fourteen miles. I inspected the wheat-fields along the way and found green bugs in small numbers in all of them, but found no indications of the presence of parasites. In the afternoon of the same day I inspected the fields of Messrs. J. H. Dietrick and S. F. Glass, the former living one-half mile east of Collyer and the latter two miles east and one-half mile north. These men had distributed parasites in their fields five days previous to my visit. In both fields I found many green bugs which had been stung by parasites. In only two cases had the parasites emerged from the body of the green bug, showing that the green bug had been stung only a short time prior to my visit. I went to the parts of the fields where the parasites had been distributed and inspected the fields for a distance of a quarter of a mile away, and found the number of bugs which were stung gradually growing less as I receded from the point where the parasites had been placed. In this case there was left no doubt in the minds of Mr. Dietrick, Mr. Glass and myself that the parasites present were due to the parasites distributed.

On my trip through the northern tier of counties to inspect the green bug situation, May 31, I got off the Rock Island train at Cuba and drove to Belleville, Republic county, a distance of eleven miles. I found very few green bugs and no indications of the parasite.

June 1 I stopped at Courtland, Republic county, and drove six miles

*Professor Glenn in northern part of state three weeks later found green bugs everywhere feeding on heading grain.

south, inspecting the fields as I went. I found a corn-field one-half mile south of town infested with the corn-root louse, but found no green bugs on corn. In a wheat-field two and one-half miles south of Courtland I found green bugs in small numbers, and occasionally one which had been stung by the parasite. The parasites had not yet emerged. On the farm of S. O. Hagaman, six miles south of Courtland, where parasites from the University had been distributed seven days before my visit, I found some green bugs, and I found about as many which had been killed by the parasite as live bugs, showing that the parasites distributed were at work. The number of parasites which had emerged was very small in comparison with the whole number I found.

June 2 I inspected a wheat-field one-half mile east of Mankato. I found no green bugs there. I also inspected an oats-field near by, and as a result of diligent search for nearly one-half hour found a small number of green bugs, and two which had been lately stung by the parasite. Parasites had been sent to Mr. Charles Poole, Lovewell, Jewell county, and Mr. C. S. Goodall, Webber, Jewell county. These men live a distance of about fourteen miles from Mankato, in a northwest direction.

June 3 I drove from Bellaire to Smith Center, Smith county, a distance of eight miles. In the fields inspected I found green bugs in small numbers, two of which had been stung by parasites. In an oats patch in the suburbs of Smith Center I searched for about fifteen minutes and found only two live bugs and no parasites.

June 4 I drove west from Norton, Norton county, four miles, and inspected the fields along the way. I found green bugs very scarce. I found a few dead green bugs from which the parasites had emerged or had been eaten by the ladybug or some other insect. The whole dorsal surface of the abdomen of the dead green bug was gone. I also found others from which the parasites had not emerged. In the afternoon I went to Clayton and inspected the fields of Mr. A. A. Castle and Mr. Harvey Allen, who live south of Clayton, and who had distributed parasites received from the University. As in other cases, I found the number of green bugs small, and a goodly number of dead bugs from which the parasites had not emerged. In the evening I returned to Clifton.

June 5 I drove from Clifton to Morganville, Clay county. I found the green bugs quite scarce near Clifton, but they increased as I approached Morganville. The parasites were plentiful and there were not many live green bugs left. The parasites had been present for some time, as they had nearly all emerged from the body of the green bug. I found no parasites any place where parasites had not been introduced, with the possible exception of Mankato, and in this case parasites had been introduced twenty miles south about thirty-five days and fourteen miles east thirteen days previous to my visit. Parasites at Mankato were very scarce.

FIELD OBSERVATIONS OF E. S. CRUMB.

Sumner county, Caldwell, April 27.—In fields south of town green bugs were moderately abundant and about fifty per cent. parasitized.

Dickinson county, Herington, May 28.—Green bugs in wheat all dead. Two oat-fields have a few aphids, but they are practically all parasitized.

Marion county, Peabody, May 20-28.—Parasites had complete control here and had killed all the aphids hatched, and gone before I left.

Kiowa county, Greensburg, June 26.—Parasites had killed the host of aphids here except in one small rye-field which was soon completely parasitized, and was free of both aphids and parasites before I left.

FIELD OBSERVATIONS OF W. S. GRIESA.

Stafford county, St. John, May 30, 1907.—Considerable damage done in this locality, but at this date all green bugs were either dead or rapidly disappearing. Very rainy weather this date.

Edwards county, Kinsley, May 31, 1907.—In every field where I have inspected the parasites have been found abundant and far outnumbering the

green bugs. On the farm of Mr. LeShure the amount of parasitized bugs was greater than I had seen elsewhere in this vicinity.

Ford county, Dodge City, June 1, 1907.—Ravages of the green bug in the wheat and oat fields were very evident, but at this date in no case did I observe either bug or parasite in any form. Cannot account for the utter obscurity of the bug.

Finney county, Garden City, June 2, 1907.—At this time the green bug is nearly exterminated by the parasite.

Reno county, Hutchinson, June 3, 1907.—In this vicinity nearly all bugs were parasitized and parasites far outnumbered the green bug.

Barton county, Great Bend, June 3, 1907.—Parasites very abundant in this section, but green bugs more abundant in proportion to parasites than I have observed elsewhere on this trip. Further damage from the green bug impossible here, I think.

For the northern part of the state I will quote from Glenn's report: "On May 29 I drove from Wa Keeney to Collyer, in Trego county, a distance of fourteen miles. I inspected the wheat-fields along the way and found green bugs in small numbers in all of them, but found no indications of the presence of parasites. In the afternoon of the same day I inspected the fields of Messrs. J. H. Dietrick and S. F. Glass, the former living one-half mile east of Collyer and the latter two miles east and one-half mile north. These men had distributed parasites in their fields five days previous to my visit. In both fields I found many green bugs which had been stung by parasites. In only two cases had the parasites emerged from the body of the green bug, showing that the green bugs had been stung only a short time prior to my visit. I went to the parts of the field where the parasites had been distributed and inspected the fields for a distance of a quarter of a mile away, and found the number of bugs which were stung gradually growing less as I receded from the point where the parasites had been placed. In this case there was left no doubt in the minds of Mr. Dietrick, Mr. Glasse and myself that the parasites present were due to the parasites distributed." (Signed) P. A. Glenn. (Extract from full report, first trip.)

"On my trip through the northern tier of counties to inspect the green bug situation, I found no parasites any place where parasites had not been introduced, with the possible exception of Mankato, and in this case parasites had been introduced twenty miles south about thirty-five days and fourteen miles east about thirteen days previous to my visit Parasites at Mankato were very scarce." (Signed) P. A. Glenn. (Summary of second trip.)

After the examination of map III and the field-notes of the observers, and map IV, which shows total number of boxes distributed, it would seem that if, as has been stated by some, the parasite will distribute itself as rapidly as the green bug does, it should, after

six weeks of artificial distribution, coupled with natural distribution from the south, have spread over the state wherever the green bugs were to be found. And further, it would seem that, with seven counties (Finney to Marion, inclusive) east and west through the south central part of the state abounding in parasites and no green bugs to prey upon, parasites should be found two and a half counties north, in Trego county, and also in those counties in the northern tier which lie three counties north of the greatest abundance of parasites. This, however, was not the case, as shown by comparison of field observers' notes. *On the contrary, with one possible exception, parasites were found in all this territory only where introduced.*

MODE AND PURPOSE OF ARTIFICIAL DISTRIBUTION OF PARASITES.

In a state of nature the parasite follows in the wake of the green bug, and advances on the green bug in accordance with its needs. Eventually it reduces the numbers of its hosts to a minimum. It did this in the southern territory, but too late to save the crop. By aiding this parasite in its distribution, transporting it from rear to van, the purpose is to hasten its work, especially where the green bug colonies are just being established.

The parasite, while growing in the body of the green bug, sticks its host to the blade of grain. And it is thus, while the parasite is maturing, that we transported them in boxes, estimated in several ways at from 20,000 to 30,000 parasites in each box. Often as many as 100 would be found attached within the space of an inch along the wheat blade.

About every seven to ten days after introduction among green bugs this parasite will increase at the expense of the pest twenty-five to fiftyfold. Professor Glenn, on the basis of twenty-fivefold increase, estimates that one female parasite placed with 2000 adult green bugs just beginning to reproduce would exterminate them in twenty-five days, and one female placed with 10,000 such adults would exterminate them in thirty days.

Early introduction thus obviously gives great advantage to the parasite. This is one point which argues strongly for the artificial distribution. It is not at all unlikely that the parasite will eventually overtake the green bug and destroy it. The past season the actual observations showed that the green bug was from 100 to 150 miles northward in advance of the parasite, and before overtaken and subdued would and did breed in sufficient numbers to seriously injure the small grains.

That is to say, the time between the date of the entrance of the

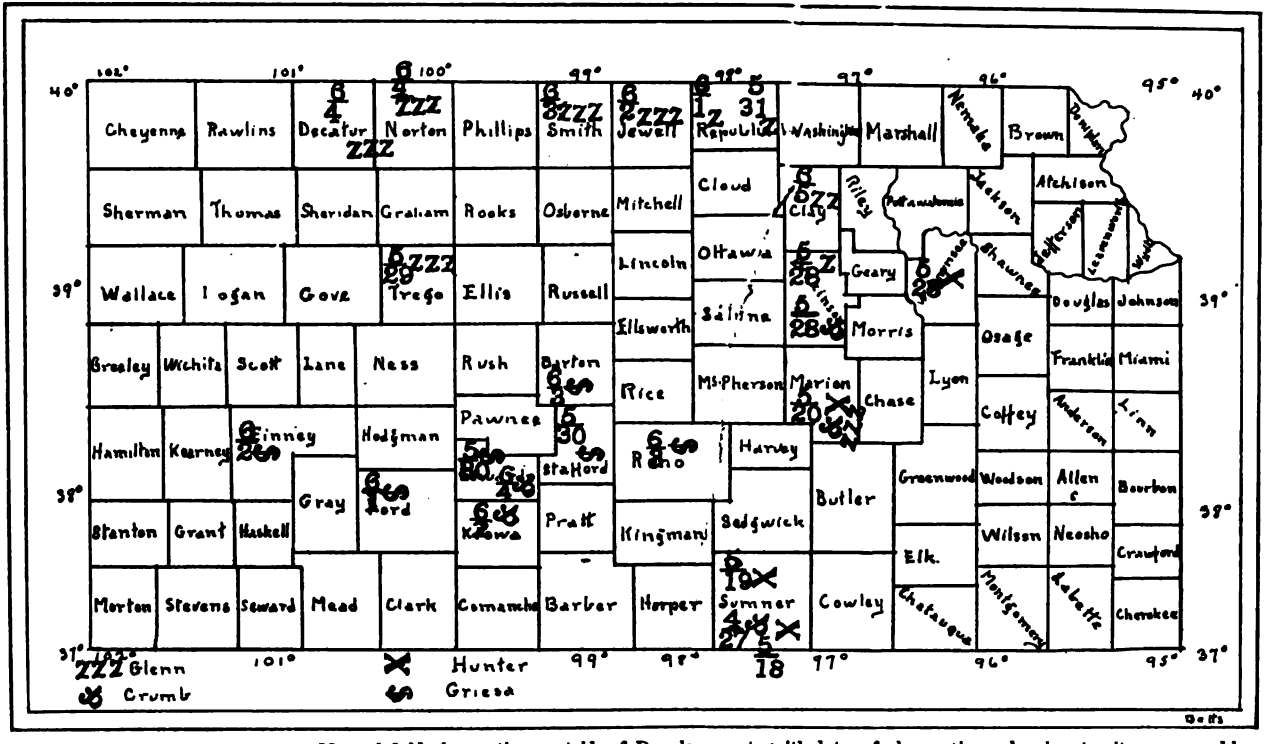


PLATE III. MAP III. KANSAS. Map of field observations outside of Douglas county with dates of observations, showing territory covered by each observer. Characters to left of name designate region examined by each observer.

six weeks of artificial distribution, coupled with natural distribution from the south, have spread over the state wherever the green bugs were to be found. And further, it would seem that, with seven counties (Finney to Marion, inclusive) east and west through the south central part of the state abounding in parasites and no green bugs to prey upon, parasites should be found two and a half counties north, in Trego county, and also in those counties in the northern tier which lie three counties north of the greatest abundance of parasites. This, however, was not the case, as shown by comparison of field observers' notes. *On the contrary, with one possible exception, parasites were found in all this territory only where introduced.*

MODE AND PURPOSE OF ARTIFICIAL DISTRIBUTION OF PARASITES.

In a state of nature the parasite follows in the wake of the green bug, and advances on the green bug in accordance with its needs. Eventually it reduces the numbers of its hosts to a minimum. It did this in the southern territory, but too late to save the crop. By aiding this parasite in its distribution, transporting it from rear to van, the purpose is to hasten its work, especially where the green bug colonies are just being established.

The parasite, while growing in the body of the green bug, sticks its host to the blade of grain. And it is thus, while the parasite is maturing, that we transported them in boxes, estimated in several ways at from 20,000 to 30,000 parasites in each box. Often as many as 100 would be found attached within the space of an inch along the wheat blade.

photograph, reduced.

About every second and the subsequent natural coming of the [illegible] period sufficiently great, according to our observations, to enable the green bug, thus unmolested, to increase in sufficient numbers to injure the crop seriously. *Artificial distribution, then, not only eliminates this period, so advantageous to the green bug, but also establishes the parasite in the field with the first green bugs as hosts, and thereafter the parasite protects the crop by preying upon subsequent green bugs as they appear.* As shown in letters already referred to, we believe that as a general rule in normal years the parasite will follow up the green bug wherever it goes and keep it in check, but in exceptional years this rule will not hold true, and was not true in Kansas spring of 1907. Probably the most notable exception last year was the fact, as

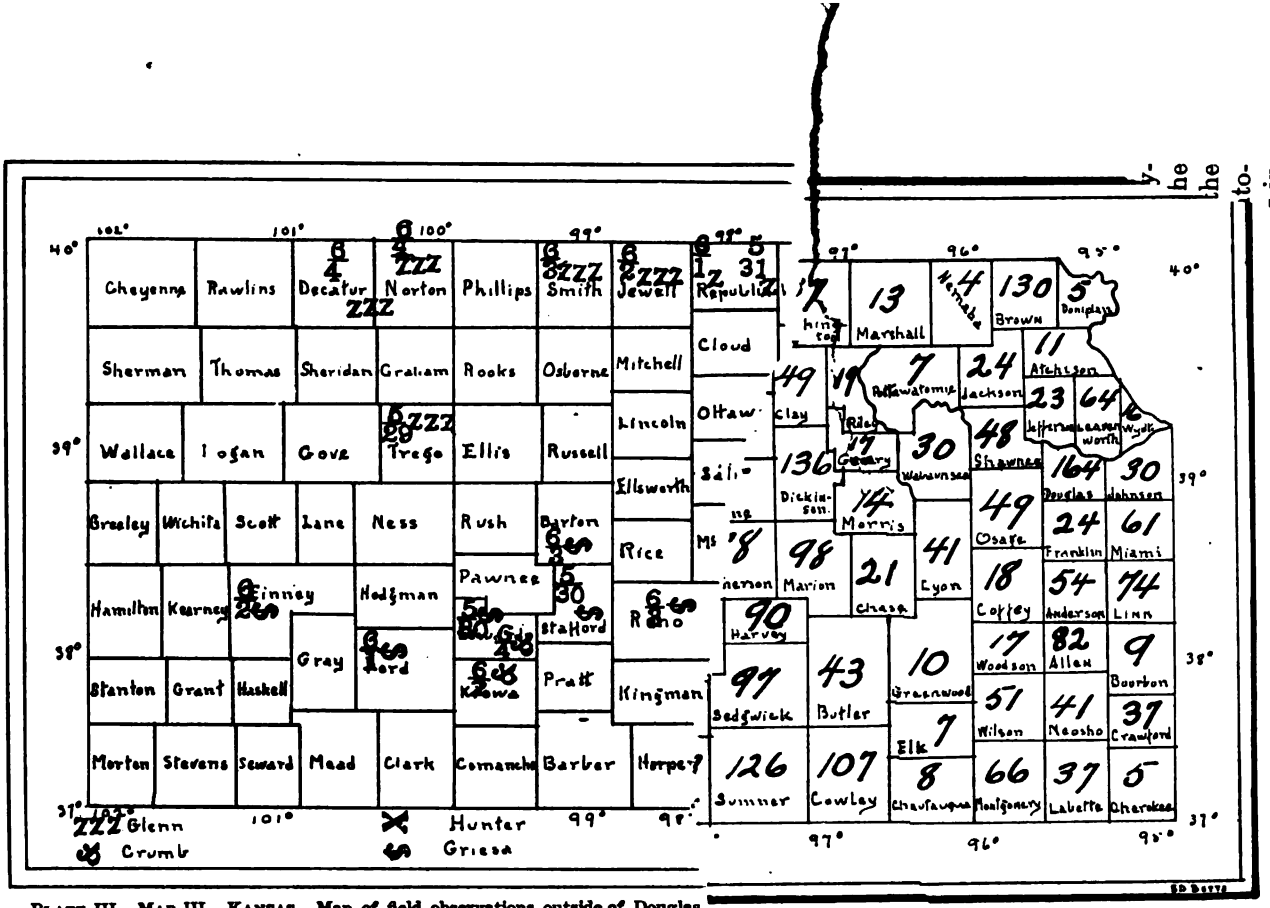


PLATE III. MAP III. KANSAS. Map of field observations outside of Douglas ach county. Total for the state, 8932. First shipment April 17. each observer. Characters to left of name designate region examined by each obser-

FIG. 16. A wheat plant showing parasitized "green bugs" sticking to leaves, illustrating form in which parasites were collected and transported. From photograph, reduced. (Original.)

green bug into the fie[illegible] parasite is a p[illegible]evented and the subsequent natural coming of the bugs this [illegible]period sufficiently great, according to our observations, to enable the green bug, thus unmolested, to increase in [illegible] to injure the crop seriously. *Artificial distri-*

[illegible]ginates this period, so advantageous to [illegible]field with

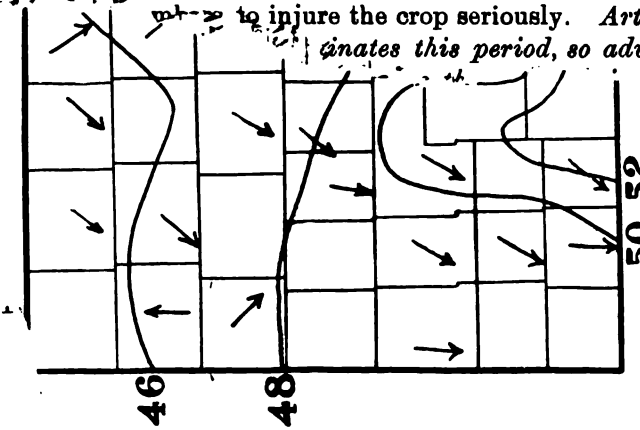


PLATE V. MAP V. KANSAS. Un[illegible] 1907. (Arrows fly with the wind.) The[illegible] of the parasite of the green bug.

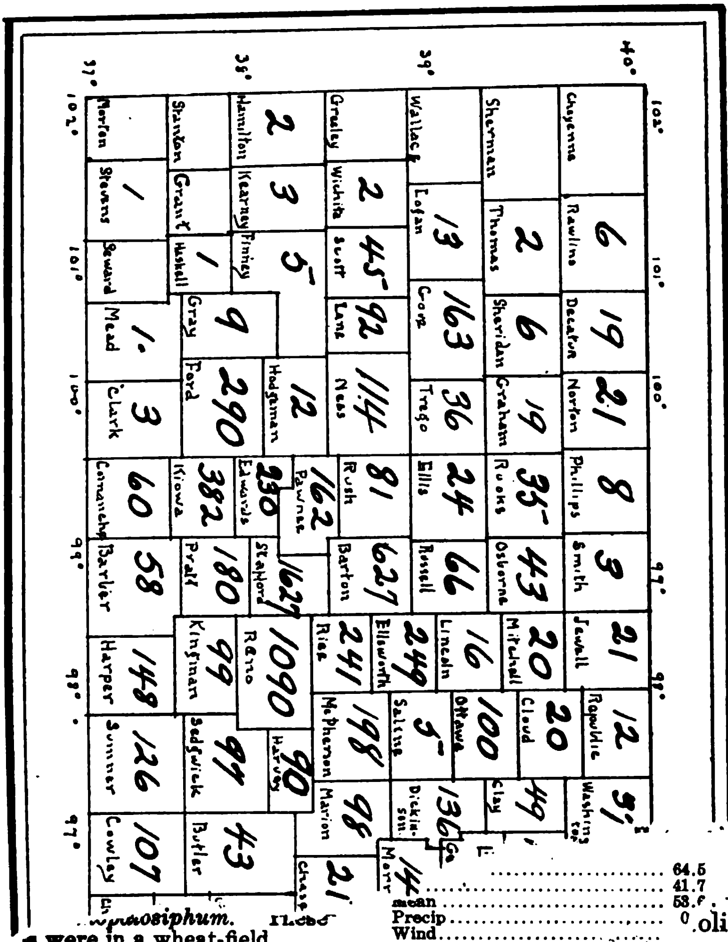


PLATE IV. MAP IV. KANSAS. Map showing number of boxes parasites sent each county. Total for the Last shipment June 6.

...*osiphum*. ...

...s were in a wheat-field.

Present in great numbers; not molested by any other insect. Wheat and oats, especially the latter, are in some fields nearly killed by it.

February 13, 1907, F...

The inimical insects are now beginning, for the first time since the green bug outbreak, to get busy around Fort Worth. The parasites are noticed very few in number.

Many present; farmers in general do not know it is here.

(*over.*)

...	64.5
...	41.7
mean	53.6
Precip	0
Wind	

...n

...olific

...M.

...sequent destruc-

...u, accompany the green ...orth facts: (*a*) The green ...r, 1906. (*b*) During the Ma... ...ed wheat shipped from twenty- ...roughout the wheat area of the ...e place. (*c*) During the ...e Federal Bureau of Ento- ...ion, examined wheat-fields in

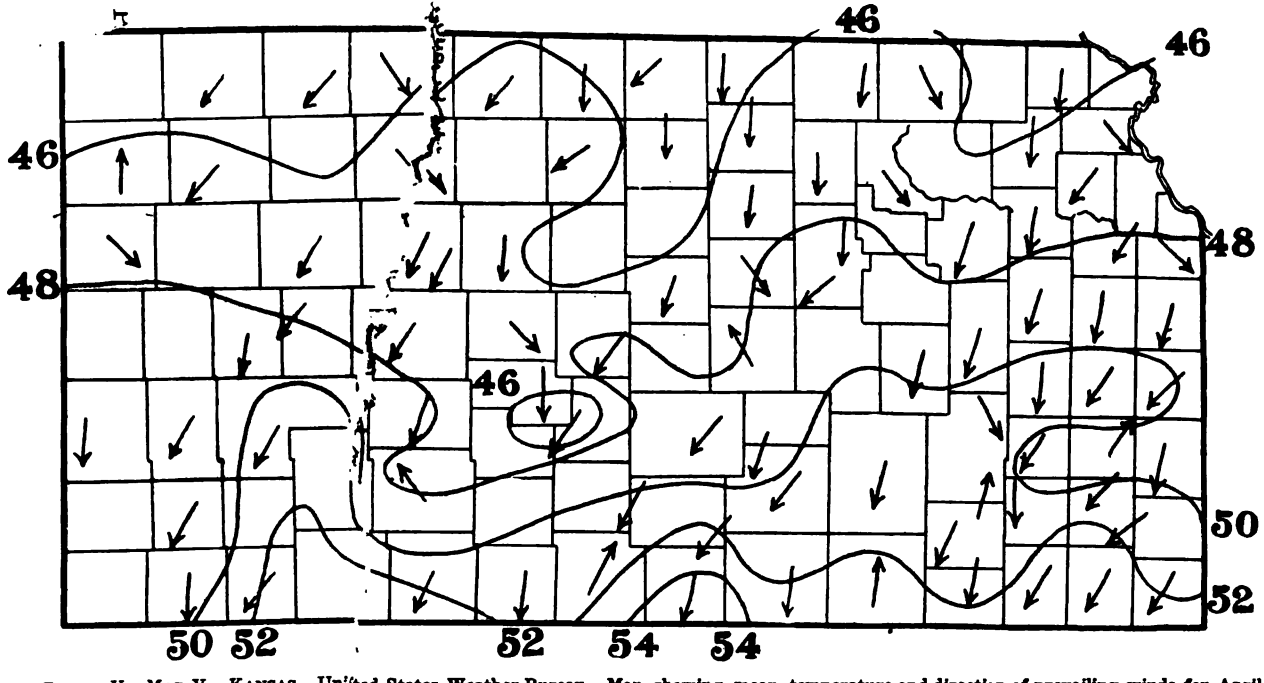


PLATE V. MAP V. KANSAS. United States Weather Bureau. Map showing mean temperature and direction of prevailing winds for April 1907. (Arrows fly with the wind.) These temperatures, together with northerly winds, illustrate a condition entirely unfavorable to the natural spread of the parasite of the green bug.

stated by Sanborn in a letter giving the area of infestation in northern Texas: "There were no parasites present in the beginning of this infestation."① The following notes show that the parasite was first seen at Fort Worth, Tex., February 13, 1907. Mean temperature for month 51.9. Mean temperature for preceding two months equally favorable for work of parasite. The same is true of other Texas points for same months. Had the parasite been present in December or January its work would have been in evidence at that time.

NOTE 1. — Mr. Sanborn very kindly furnished us a transcript of his field observations while following the course of the green bug up through Texas and Oklahoma.

Weather observations from reports of United States Weather Bureau for times and places visited by Sanborn (as noted opposite).

December 9, 1906, Allen, Tex.

Several by mail; none parasitized; sent by Mr. O. Floyd, R. F. D. No. 1.

DECEMBER.

(Data for Dallas, about twenty-two miles south.)

Max	83
Min	26
Mean ..... (51.60; normal)	55.40
Wind	S.
Precip	2.08

December 22, 1906, Plano, Tex.

Present in great numbers; killing oats in patches. They seem to have originated in a branch here and to have soon colonized the surrounding fields.

Plano is about fifteen miles north of Dallas. See above.

January 6, 1907, Howe, Tex.

Investigated conditions of wheat- and oats-fields here. No inimical insects present. Aphids numerous and alike on wheat and oats. Seem to be universally present. Barley not infested.

Saw one *Megilla maculata* and one *Scymnus* here; concealed under turnip tops, which were infested with a *Rhopalosiphum*. These turnips were in a wheat-field.

Present in great numbers; not molested by any other insect. Wheat and oats, especially the latter, are in some fields nearly killed by it.

JANUARY.

(Data for Sherman, seven or eight miles north of Howe.)

	1	2	3	4	5	6
Max	60	62	58	60	58	56
Min	48	47	44	33	43	41

Monthly mean:

Max	64.5
Min	41.7
Mean	53.[illegible]
Precip	0
Wind	

February 13, 1907, F[illegible]rth, accompany the green bug outbreak, to get busy around Fort Worth. The parasites are noticed very few in number.

Many present; farmers in general do not know it is here.

facts: (*a*) The green [illegible]r, 1906. (*b*) During the Ma[illegible] Mi[illegible]ed wheat shipped from twenty- [illegible]roughout the wheat area of the [illegible]n[illegible]e place. (*c*) During the [illegible] Me[illegible].e Federal Bureau of Ento- [illegible]ion, examined wheat-fields in

(over.)

[illegible]olific

[illegible]s.

[illegible]sequent destruc-

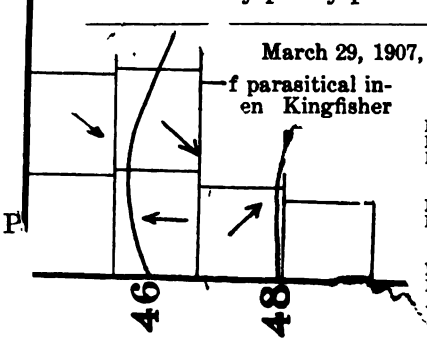
RESULTS OF THOROUGH AND INTELLIGENT CULTURE.

The one regret of those conducting the work of artificial distribution was that lack of funds prevented an unlimited supply of material being sent in far larger quantities than were sent. When the parasites have arrived artificial distribution is not necessary. That is, let me repeat, artificial distribution is a preventive fortifying the field against serious attack, not a remedy dealing with the situation after the forces of the green bug are there in full sway.

Thus far we have considered how we could adjust this disturbed equilibrium—this sudden inequality—by natural forces. Is there nothing the farmer himself can do? Last spring, when traveling through the territory where damage was the greatest, I was much impressed by the absence of uniformity in effects. One field would be seriously damaged and another be, apparently, little the worse. Soft wheat was more seriously affected than other varieties, but this did not explain all.

The explanation came best in a very practical illustration. In traveling over the country with Mr. Geo. A. Hunter and his son-in-law, Mr. W. T. Voils, president and vice president, respectively, of the Hunter Milling Company, both of Wellington, we came to a field of soft wheat. The north half was almost or entirely dead, the ground exposed, no heads having formed. The south half promised a good yield. I asked Mr. Hunter to obtain for me the history of this field, and in reply to my letter some time ago, I have the following:

"MY DEAR MR. HUNTER—In reply to your letter of December 3, 1907, will say that I have investigated with reference to the wheat crop grown on the quarter-section of land south of the roundhouse, and I find that the piece of wheat on the north side, or next to the hedge, had been sown in oats the year previous and that it was ...ved late and very poorly plowed and sown in wheat very late in



March 29, 1907, Enid, Okla.

FEBRUARY.

	1	2	3	4	5	6	7	8	9
Max.....	64	55	65	52	70	73	54	53	59
Min.....	22	32	28	30	29	32	33	32	40
Precip.....	—	—	—	—	—	—	—	—	.20
	10	11	12	13	14	15	16	17	18
Max.....	40	68	45	60	62	65	70	82	90
Min.....	33	35	36	33	30	31	34	39	45
	19	20	21	22	23	24	25	26	27
Max.....	100	99	94	93	86	92	91	84	—
Min.....	55	57	58	62	62	50	59	59	56

Mean for month:

Max.....	71.8
Min.....	41.2
Mean.....	56.5
Wind.....	S.

the fall, and if you will remember it came up late and was very tender in the spring, and the result was the green bugs got it all.

"The south half had been sown in wheat the year previous and was plowed early and deep last fall, and sowed in wheat early, and was well cultivated. The wheat came up early in the fall and got a good start, and this spring it was in good shape and kept ahead of the green bugs and the result was a good crop of about seventeen bushels per acre.

"I hope the above information will be perfectly satisfactory to you; if not, I will be glad to give you any further information that you may wish. (Signed) GEO. A. HUNTER."

Here, then, is an excellent object-lesson. Thorough culture gives the plant vigor and rapidity of growth, enabling it to withstand the attack. Another and more important lesson comes to us from the field observations of this fall. In our field-work we have found green bugs present only where volunteer oats had been allowed to stand. For instance, in one field of wheat, part had been in oats and part in millet last year. This year green bugs are present in this wheat-field only where the volunteer oats came up after plowing. The ground in millet last year has no green bugs. Had these various fields been disked and repeatedly disked after plowing the oats would not have stood to attract and furnish food to this inimical insect.

The grasshopper taught us to disk our alfalfa, thereby materially increasing the yield. If the green bug should make more thorough culture a necessity, might we not call it a blessing in disguise when the increased yields were garnered?

SUMMARY.

In conclusion, summing up the whole matter briefly for the year 1907 in Kansas:

1. The green bug, an imported species, entered Kansas from the south, and on this, its first appearance, proved to be prolific and capable of causing serious injury to small grains.

2. The greatest check to its increase and consequent destructiveness was a small, wasp-like, parasitic insect.

3. This parasite did not, during this period, accompany the green bug as it spread, as shown by the following facts: (*a*) The green bug was present in Kansas in December, 1906. (*b*) During the first two weeks of April, 1907, infested wheat shipped from twenty-eight widely separated localities throughout the wheat area of the state showed parasites present in but one place. (*c*) During the same period of April an expert from the Federal Bureau of Entomology, sent here to study the situation, examined wheat-fields in

nine different parts of the state and found those places free from parasites, except at one point on the southern border, where, he states, "they are beginning to appear." (*d*) Field experiments showed that parasites were absent until introduced. (*e*) Early in June, after weather favorable to both the artificial and natural distribution of the parasites, a conservative, trained observer found a large area in the northern part of the state where green bugs were present, but parasites, with one possible exception, present only where introduced. (*f*) During the month of April climatic conditions, both as to temperature and winds, were entirely unfavorable to natural distribution of parasites. (*g*) A serious outbreak of the green bug is reported from Washington, D. C., unattended by the parasite, and this at the close of July, a season most favorable for the activities of the parasite. (*h*) According to Sanborn, the expert already quoted, who was detailed by the Federal Bureau of Entomology to study the problem in Texas, "the parasite was not present in the original area of infestation at the time of the outbreak."①

4. In view of these facts, artificial introduction of parasites was undertaken by the University, largely as an experiment, with the hope that by thus aiding the parasite in its work the green bugs

---

NOTE 1. As the final proof of this report is being read, another notable illustration of the fact that the parasite does not accompany the green bug even under the most favorable conditions came to our notice. On May 17 a canister of wheat infested by green bugs was received from Mr. R. H. Robinson, of Altus, Okla. In this can there were 63 stalks of wheat and 2013 green bugs. There were no parasites among these on their arrival and none appeared thereafter, though the green bugs were kept for observation under proper conditions for about a month.

On May 19 Professor Glenn began an examination of the wheat fields of this portion of Jackson county, Oklahoma. After three days spent in careful examination of fields over an area of about forty square miles the distribution of green bugs was general, but no parasites were found. Mr. Robinson stated that a representative of the Federal Bureau of Entomology had been there about a month previous to Mr. Glenn's visit and that he was unable to find any parasites.

A letter from Mr. Robinson under date of June 18, 1909, states:

"The green bugs continue the same as when Mr. Glenn was here, with no parasites in evidence."

At the conclusion of his report upon conditions in this region, Professor Glenn gives the following summary:

"1. The green bugs had been present the preceding season and had passed the summer in the volunteer grain and grasses which were abundant on account of the moist summer.

"2. The green bugs passed the winter in the fields.

"3. No parasites have been present this spring and probably none were present last season.

"4. Conditions throughout this section of the country were favorable for a wide-spread infestation.

"5. All the conditions here confirm the views set forth in our forthcoming bulletin."

would be kept in check in places where they had not yet become so numerous as to be destructive, and thus prevent damage which threatened crops; and from observations this experiment has been attended with such a degree of success as to warrant us in concluding that artificial introduction of parasites is practical.

5. Thorough preparation of the soil and proper seeding enables the plant to resist in a large measure the attack of the green bug. Late plowing, or removal of all volunteer grains by disking, will force the green bug to seek elsewhere for summer food-plants, and many are likely to perish in the seeking. Volunteer grains allowed to stand not only furnish food upon which they thrive exceedingly well, but hold the green bug readily accessible to the forthcoming seeded crop.

LAST CIRCULAR OF THE FEDERAL BUREAU ON "SPRING APHIS, OR (SO-CALLED) GREEN BUG."[1]

This circular summarizes for the most part previous articles of the Bureau of Entomology upon this subject. The meteorological data included are of great interest in their bearing upon the life of the green bug. This phase of the subject will be treated later in this report.

In this circular, however, the writer arrives at conclusions at variance with those resulting from experiments and observations conducted by the University. And further, surprising as it may seem, he essays to pass judgment upon these experiments without acquainting himself with the data governing them. In the light of present information, it would seem fitting, then, to see wherein there might arise a possibility for such difference in conclusions as lie between the conclusions of the above circular and those of this bulletin.

According to this circular, Mr. Webster left Washington for Kansas on May 13 (p. 10). An assistant, Mr. Ainslee, had been located at Wellington since March 30, with a brief stay at McPherson and Sterling, and it is upon the observations of these two field agents at the places and from the times given that this circular is issued. Mr. Webster states: "During the last two weeks of April a great many small lots of parasites were distributed over the southern and central counties of Kansas by Mr. S. J. Hunter, of the Kansas State University. The artificial sending out of these parasites by Mr. Hunter and the test of distributing an enormous quantity in a single field, described above, were legitimate experiments, but the evidence showed very conclusively that they resulted in no benefit whatever."

He bases these conclusions upon the experiments carried on under his direction at Wellington, McPherson and Manhattan, where the parasite was already present and the assertion that parasites were present everywhere, being carried along with and traveling with the winged forms wherever they went.

As to the experiments, it should be noted that in each case they were carried on in localities where the parasite was already present. This being the case, it is not strange that there were not enough visible results to warrant the artificial introduction where parasites

1. Circ. No. 93, U. S. Dept. of Agr., Bureau of Ent., by Mr. F. M. Webster, agent U. S. Bureau of Ent., issued August 22, 1907.

already are present. Hence, so far as these experiments are concerned, we agree with him that they were of no practical value. But they do not prove that artificial introduction in localities where the parasite does not exist is useless.

As to the character of our results it is clearly evident that Mr. Webster is not in a position to give an opinion upon the experimental work of the University in this matter, since, as his statements show, he has no idea of or definite knowledge of the work conducted by the University in the state in general, or in the field experiments in particular. Had Mr. Webster come to the University, examined the work done and being then performed, and observed the field-work, as we very much wished him to do, his opinion in this matter would then have had full bearing upon the results. As the matter now stands it is difficult to see how he is able to express an opinion worthy of consideration as to the results of the University's experimentation in this matter.

From his repeated assertions that parasites were and of necessity are present everywhere we dissent. They may have been present wherever he and his assistants made observations, but this bulletin will show that they are not present everywhere, and his own report (pp. 5, 8) shows two instances at least where the green bug existed unattended by the parasite.

For the first instance his report reads: "A quite serious outbreak of the green bug is at present (July 25, 1907) in progress on the grounds of this department at Washington, and chiefly on bluegrass. . . . AND ESPECIALLY IS IT NOTABLE IN VIEW OF THE TOTAL LACK OF *Lysiphlebus tritici*, THE MOST IMPORTANT OF THE NATURAL ENEMIES OF THIS APHIS."

It is especially surprising that there were no parasites present in this case at this late date if the following statement (p. 15) is correct: "The very act of migration of the green bug, therefore, brings the parasite, and there is no need of artificial introduction, for if the center from which the green bug is migrating has the parasites, as it always does" [Texas last year furnished a notable exception to this], "the latter are of necessity carried by their host; and furthermore, the adult parasites fly with the latter with favoring winds;" and more so in view of the fact, as the report sets forth (p. 13), that in western North Carolina parasites were literally swarming on April 20, and on the same date (p. 12) they were present at Richmond, Va. The weather reports show that in Washington, in 1907, the mean temperature for April was 49.4° F.; for May, 50.2° F.; for June, 65.9° F.; and July, 75.8° F. On page

4 he states that the parasite is active only above 56° F. (We have observed it ovipositing at 39° F). This being the case, temperature conditions in Washington had been favorable for nearly three months at the time (July 25) of which he writes, and still there was, he states, "total lack of *Lysiphlebus tritici*." This is indeed a notable exception, and there are others, as my report shows.

It seems strange that after seeking so diligently throughout the East and West for a favorable place to test the practicability of the introduction of the parasite that this opportunity was not improved. Had the parasites been introduced here, and no practical results followed, the experiment would have had some weight, but the other experiments described in the report prove nothing, because, as he states, parasites were already present.

For the second exception Mr. Webster records (p. 8) that in the vicinity of Wellington the green bugs were present, but even after two days' search no parasites were found. Now had his assistant gone up through Kansas he would have found green bugs abundant from sixty to ninety miles north, unattended by the parasite, as shown by Sanborn's report.

Had Mr. Webster referred to Mr. C. E. Sanborn's field report for Kansas, he would have found eight Kansas localities examined by Mr. Sanborn where green bugs existed unattended by the parasite. (Mr. Sanborn is also an agent of the Bureau of Entomology, and a specialist in this particular group of insects, and had followed this outbreak from the beginning.) His field reports were no doubt accessible to Mr. Webster while preparing this circular. Had Mr. Webster included Mr. Sanborn's field reports in this circular he could not then have stated that the parasite coexists with the green bug.

Had Mr. Webster accompanied Mr. Glenn on his two trips across the northern part of this state he would have found that his theory of the coexistence of this host and the parasite did not hold good. (See Glenn's report.)

As shown in letters already referred to, we believe that, as a general rule, in normal years the parasite will follow up the green bug wherever it goes and keep it in check, but in exceptional years this rule will not hold true, and was not true in Kansas last spring.

We agree with this circular that "During strong winds the *Lysiphlebus* does not use its wings, but crawls about over the plants and probably does not become scattered by the gales" (p. 15.) This does not harmonize, however, with the preceding statement—"The adult parasites fly with the latter with favoring winds." No record

is contained in this circular of the commonly known fact that the winged green bug takes every advantage of these gales and that on such days it readily takes wing and is thus transported. Crumb's field-notes, written while at Enid, cover this point. "Apparently they make no extensive efforts at flying except on windy days, when they make driving in the country and even in the city very disagreeable. I saw one cab driver at Enid wearing goggles to keep the green bugs out of his eyes." That is, while the green bug is being widely scattered by gales, the parasite is clinging close to its place of support.

Mr. Webster does advise artificial use of the natural enemies of the green bug in centers of original infestation (p. 13), but states on page 15 what was the case during the winter of 1907–'08 in Kansas, but was not so in Texas the year previous—that these centers already have the parasite *Lysiphlebus*. Then since, as repeatedly stated in the circular, artificial distribution is unnecessary in the presence of existing parasites, there should have also appeared reasons why artificial use of parasites is here necessary. Without such it would seem there results from what precedes a conflict in statements. Our observations have shown, on the contrary, that the parasites must be taken from these centers to combat the green bug in new localities to which it has escaped unattended by the parasite.

The supposed mode of transportation of the parasite within the winged green bug is, according to Mr. Webster, brought about as follows: "As stated, many of the green bugs are stung by the *Lysiphlebus* while quite young, and if these develop to winged adults, as they at times do in myriads, and drift away to distant fields, they carry the parasite with them in their bodies."

This, we see, is entirely theoretical and problematical, and has no basis in fact other than the illustration of a parasitized migrant which, as far as we know, may have died at the place where parasitized. As to the evidence in the case, during favorable growing weather the green bug matures in seven days. The newly stung green bug under the most favorable conditions shows the presence of the internal parasitic grub in thirty-six hours afterward and dies within three days. Obviously the chances then are very much against the immature green bug developing into the winged form to transport the parasite gnawing within it to new fields. As stated elsewhere in this bulletin, strong evidence against this theory is found in the numerous places where the green bug has existed in destructive numbers unattended by the parasite.

Summing up this circular briefly, the meteorological data have an important bearing upon the problem; the publication as a whole, however, does not measure up to the standard set by the Bureau of Entomology of the United States Department of Agriculture, for the following reasons:

First.—The author essays to pass judgment on an extended series of experiments without having made an examination of the data pertaining to these experiments.

Second.—All the evidence in the possession of the Bureau at that time is not presented, and this suggests a desire on the part of the author to reach certain conclusions.

Third.—The facts set forth do not harmonize, and the presentation therefore becomes inconsistent with itself.

Fourth.—The conclusions given are based in part on unsubstantiated theory, and for the rest on a limited number of experiments performed under conditions wherein the true value of such experiments could not become apparent.

HEARINGS BEFORE THE COMMITTEE ON AGRICULTURE.

January 9, 1908, the Hon. Charles F. Scott, chairman of the Committee on Agriculture of the House of Representatives of the United States, wrote for a copy of the report concerning the work on the green bug conducted by the Department of Entomology of the University. The full report being not yet complete, a copy of the paper read before the Kansas State Board of Agriculture on January 10 last was sent to him January 14. On May 26 a copy of the "Hearings"[1] before this committee was received.

On January 29 the committee reached consideration of the estimates for the United States Bureau of Entomology, and pages 488 and 498 of the Hearings are devoted to the subject of the green bug, dealing principally with the experiments conducted by the Federal Bureau of Entomology and by the University of Kansas.

For our purpose at this time the presentation and consideration of this portion of the Hearings are probably best attained by quoting direct from the committee's report itself.

ON CONTROL OF GREEN BUG BY PARASITE.

The chairman asked Doctor Howard, chief of the Bureau, whether there was a reasonable hope of controlling the pest by artificially spreading the parasite, as was done by the University last year?

Doctor Howard replied: "I think there is good ground for experimentation; a good field for experimentation. I should like to see the experiments carried on more than they have been. I do not contend that our experiment of last spring was a conclusive experiment; it is possible that they may find that under varying weather conditions these experiments, under certain circumstances, may succeed." (Page 491.)

This is in entire accord with what the writer said before the Kansas State Board of Agriculture January 10 last, and recorded in their proceedings (also found in this report), viz.: That in the beginning we fully believed the parasite would accompany the green bug and thus keep it in check, but when under existing conditions it did not accompany the green bug the artificial distribution was undertaken, and thus the work of the parasite was hastened

1. House of Representatives, United States. Hearings before the Committee on Agriculture of the Honorable Secretary of Agriculture and Chiefs of Bureaus and Divisions of the Department of Agriculture on the Estimates of Appropriations for the fiscal year ending June 30, 1909, also of members of Congress and other persons interested in matters pertaining to the Department of Agriculture and the Committee. Sixtieth Congress, First Session. Washington, Government Printing Office, 1908.

by transporting it from the rear to the van of the green bug invasion.

Mr. Marlatt, Doctor Howard's chief assistant, however, speaks before this committee with assurance regarding the definite results obtained by their experiments, and, based on these experiments, gives it as his opinion that the work conducted by the University was of no avail.

Quoting in full from the Hearings, giving the names of the members of the committee asking questions:

THE GREEN BUG DOES PRECEDE THE PARASITE.

"MR. BEALL: Take Doctor Hunter in Kansas. He says: 'On the 14th of April last year it was evident from reliable sources, namely, the packages of infested wheat referred to, and reports, after personal examination, of Agent Sanborn, of the Federal Bureau, of areas shown in the accompanying chart, that the green bug was present throughout the wheat area of the state (Kansas), and the principal natural enemy, the parasite, was not found anywhere in the state except at one point on the extreme southern border; that the weather conditions were such as to hinder if not preclude its wide distribution naturally.' Is that in consonance with your investigation?

"MR. HOWARD: What was that date?

"MR. BEALL: The 14th of April.

"MR. HOWARD: That does not necessarily conflict with our ideas. Perhaps by the first of May the parasites would have been present in great numbers, or, if the weather were favorable, perhaps earlier." (Page 490.)

It was for the express purpose of eliminating these two weeks' time that the work of transporting the parasites was undertaken by the University, for, as shown elsewhere in this report, the parasites will work on the green bug at hand at a much lower temperature than they will migrate to new fields.

CONCLUSION FROM FACTS PREVIOUSLY STATED.

"MR. BEALL: Mr. Hunter further states: 'These experiments showed that parasites were absent until introduced.' Would you agree with that?

"MR. HOWARD: No; because he does not give any facts as to how many he counted or how close the observations were or about the condition of the weather, which we have shown is the controlling factor."

The quotation just read by Mr. Beall is from the conclusions. The facts which Doctor Howard calls for are given in the body of the paper from which Mr. Beall was reading. This paper is now a part of the report of the Board of Agriculture already referred to and contains these facts on pp. 41-47. In this bulletin the same details are recorded.

TWO CORRECTIONS.

Doctor Howard and his associates will doubtless be glad to be set aright in the following two instances—I and II.

I.— *Was the parasite present in the Washington instance?*

"MR. BEALL: What would you say of a conclusion like this, which was reached by Doctor Hunter: 'A serious outbreak of the green bug is reported from Washington, D. C., unattended by the parasite, and this at the close of July, a season most favorable for the activities of the parasite'?

"MR. HOWARD: We found the parasite here at that time. I do not know how the report got out; possibly through some newspaper man here in Washington." (Page 496.)

Our information concerning the entire absence of the parasite in the above case did not come from some Washington newspaper man, but from two sources within Doctor Howard's own Bureau:

(1) Circular No. 93, of the United States Bureau of Entomology —published four months previous—and elsewhere referred to, and written by Mr. Webster, of that Bureau, says, on page 5:

"Strangely enough, and happily for our investigations, a quite serious outbreak of the green bug is at present (July 25, 1907) in progress on the grounds of this Department at Washington, and chiefly on blue-grass, though the insect is also breeding on crab-grass (*Syntherisma sanguinalis*).

"This outbreak on the grounds of the Department of Agriculture is notable in some respects, in that the continued close cutting of the blue-grass has supplied a continual fresh, tender growth as food for the green bug, thus preventing the development of winged females to escape; *and especially is it notable in view of the total lack of Lysiphlebus tritici*, the most important of the natural enemies of this aphis. The only natural enemy found in this case feeding upon the green bug was the diminutive black and yellow beetle (*Hyperaspis undulata*), not previously known in connection with this pest."

(2) Another member of the staff of the Federal Bureau of Entomology, detailed on this Washington instance, was in our laboratory December 6, 1907, and wrote in our field-note book the following:

"WASHINGTON, D. C., July.—About the first and second week in July, 1907, an outbreak of *Toxoptera graminum* was observed on the Department of Agriculture grounds. The *Toxoptera* were quite numerous on the blue-grass, the blades often being covered on the under side. The blue-grass leaf is folded and it is between these folds that they are thickest. The grass was damaged and in spots almost killed out. *There were no Lysiphlebus as late as 31st of July among the aphids.*"

II.— *Were Glenn's experiments reviewed?*

"MR. BEALL: Further he says: 'Early in June, after weather favorable to both the artificial and natural distribution of the parasites, a conservative, trained observer (Glenn) found a large area in the northern part of the state where green bugs were present, but parasites, with one possible exception, were present only when introduced.'

"MR. HOWARD: I should say in all probability three days later he would have found plenty of parasites there.

"MR. BEALL: This is a report covering the entire period of the infestation of the fields of Kansas.

"MR. HOWARD: Yes.

"MR. BEALL: And these are the conclusions drawn by Doctor Hunter, who is, I understand, state entomologist for Kansas, and his conclusions are at absolute variance with the conclusions announced by you. In that state of the case, can it be said that experiments have progressed far enough for entomologists to agree upon a definite statement of what can or cannot be done with reference to the extermination of the pest?

"MR. HOWARD: As a matter of fact, Mr. Marlatt tells me that immediately after those statements you are just reading were made public last year, Mr. Webster and Mr. Ainslee, of the Bureau of Entomology, went to those same fields and found the conditions radically different. That does not mean that Mr. Hunter or the people he was quoting were dishonest, but it means that as soon thereafter as our men could get there the parasites were present. As soon as the warm, bright weather comes, within a few days the parasites will practically always be found." (P. 496.)

To know that the men of the Bureau of Entomology had indeed in reality reviewed a small part of the work of the University in this matter was welcome news, especially since the feeling existed that they had passed judgment without any acquaintance whatever with the conduct of the work. And yet, since no reports of these two trips by Professor Glenn had ever been given out it hardly seems plausible that these men referred to by Doctor Howard should have gone over this same territory. Mr. Glenn, however, wrote to the farmers in the different counties, in whose fields he worked and who worked with him, to ask if any one since that time had visited any of those fields to study in any way the green bug problem. The answer in every instance was that Mr. Glenn was the only man that had ever been in those localities on a mission of that kind. Mr. Glenn also wrote the liverymen in some of the small towns where it would be necessary to secure transportation to those places where Glenn had made his observations, and the same answer was given, that no person or persons had been through that locality investigating the green bug problem except Mr. Glenn himself.

When it is considered that Glenn's account of these two northern trips occurs for the first time in the paper before the Kansas State Board of Agriculture January 10 last, it seems all the more probable that the men referred to by Doctor Howard did not go over this territory.

Now all this should not reflect on Doctor Howard or his assistants. Doctor Howard was at this time in Russia; Marlatt was in Washington; Webster did not leave Washington until May 13, and then went to the southern portion of the state, where the parasite was at that time in control. Ainslee got to the southern border of Kansas April 1, found the green bug but no parasite, turned back, and his subsequent observations in Kansas were at but two or three places in the state.

It is not to be marveled at that none of these men agreed either with themselves or with the results obtained from the work conducted by the University.

The one man who gave the matter thorough consideration was Sanborn, and of him and the others Doctor Howard speaks to the committee as follows:

"MR. BEALL: How long has this been under the consideration of the Department—this problem?

"MR. HOWARD: I think Mr. Sanborn has been on it for two years now; he is our agent in Texas. Mr. Webster, and his field force which he sends through the country, has been only handling it the last year." (Page 495.)

Sanborn, who has been on this problem for two years, was at the place of original infestation at the time of the outbreak and followed the migration all through Kansas, making observations and deductions that are in entire accord with those made and drawn by the members of this department at the University.

Summing up this hearing then, Doctor Howard and Mr. Marlatt are at variance as to the value of their own experiments.

Doctor Howard it seems is in error regarding the presence of the parasite at the serious outbreak in Washington, D. C.

It would seem, also, that Doctor Howard has been misinformed regarding the review of a very important phase of our work by Mr. Webster and Mr. Ainslee, of the Federal Bureau of Entomology.

Sanborn, of the Federal Bureau, who has given all of his time exclusively to this line of investigation during the past two years, in his observations and deductions corroborates the results obtained by the Department of Entomology of the University of Kansas.

INSECT IN COMBAT WITH INSECT—ITS PRACTICAL USE.

In view of what has been said and what is to follow, a discussion of this method of insect control—the utilization of one insect in combating another—may properly here include opinions and experiences of others upon this subject.

Insects thus used are of two kinds, depending upon their mode of attack: (*a*) Parasitic insects, those living in or on the bodies of the injurious form, an existence fatal to the host; (*b*) predatory insects, those that feed directly upon the bodies of the inimical forms. In this order they will be considered.

(*a*) UTILIZATION OF PARASITIC SPECIES.

Dr. H. T. Fernald,[1] in writing on "The Future of Economic Entomology," after reviewing methods used from the beginning of this science and setting forth the fact that such measures as spraying, fumigation and the like, while effective in themselves have never come into common practice, though advocated for years, suggests a plan by which it might be possible for these measures to come into more general use under state direction. "But where does the economic entomologist stand if this plan fails? For years he has urged, taught and demonstrated spraying methods as effective, and he knows that he is correct. But when his advice is for years persistently rejected by a large proportion of the people, as is still the case, it is certain that the time has now come to place economic entomology on a broader and more scientific foundation."

After discussing its various possibilities, he concludes:

"If economic entomology is to attain success during the present century, then it will be by inducing a more general adoption of the methods of treatment now known but not used generally enough; by the production of new, pest-resistant varieties of plants by experimental plant breeding; and by utilization of all the parasitic forces the world has available, establishing the parasites where their services are most needed and as free as possible from their own enemies. The old methods have proved too nearly useless because they have been so little adopted."

In an article on "Value of Insect Parasitism to the Farmer," published June, 1908, F. M. Webster concluded:

"This whole matter of artificial manipulation of parasitic enemies of insect pests affecting cereal and forage crops is an effort to aid the

1. *Popular Science Monthly*, February, 1908, pp. 174–178.

farmers of the United States by keeping the whole country under a system of surveillance. When it is found that any destructive pest is rapidly increasing in one section, by the transportation and colonization of great numbers of the parasites of that particular pest from some other part of the country, where it is known to be abundant, at the proper time and under favorable conditions, it is hoped that we may be able to forestall and control, if not indeed ward off, many of these destructive outbreaks of insect pests. This is a tremendous problem, involving difficult tasks that can be followed out only by long, patient, exact, and faithful investigations, where failures and disappointments are to be expected and must be overcome."[1]

Writing upon this very subject,[2] Prof. Paul Marchal gives an account of the utilization of these parasitic insects:

"It is in this way, for example, that Decaux, struck by the multitude of ichneumon flies, or braconids, which came out of the buds of apple attacked by *Anthonomus*, advised, in place of immediately burning these buds, as was generally done, preserving them in boxes covered with gauze, raising the latter from time to time during the period of issuing of the parasites so as to permit them to escape. In 1880 he put this method into practice and collected in Picardy buds reddened by the *Anthonomus* from 800 apple trees, amounting to five hectoliters, and thus accomplished the destruction of more than a million *Anthonomi*, and set at liberty about 250,000 parasites which the following year were aids in the destruction of weevils. The orchards treated being isolated in the middle of cultivated fields, it sufficed to repeat the same operation the following year in order to stop all serious damage during ten years.

"This plan started by Decaux has been perfected by Berlese (1902) in order to protect the parasites of the *Cochylis*. This author recommends the use of boxes with the cover pierced by a window, being also covered by a metal plate perforated with holes 2 mm. in width. In the autumn there is placed in the box nearly full-grown larvæ with the leaves necessary for pupating. In the springtime the parasites will issue through the openings, while the moths perish in the box. There is no reason why this method should not be adopted on a large scale, replacing the box by a room in which the window is closed by means of a wire screen. A similar method could be employed with a number of other insects, and quite recently (1907) Silvestri had advised it for the olive fly in arranging a plan of defense against this insect, based both upon the protection to parasites and on cultural methods.

"Johnson, in 1899, having put some fragments of twigs covered with the San Jose scale in a series of tubes, obtained more than a thousand parasites (*Aphelinus fuscipennis* Howard) in each of them. Struck by this observation, he recommends the protection

1. Yearbook of the Department of Agriculture for 1907, p. 255, published June 1, 1908.

2. "The Annals of the National Agronomical Institute" (Superior School of Agriculture) second series, vol. VI, part II, Paris, 1907, pp. 291-354, and translated in the *Popular Science Monthly* of April, 1908, pp. 352-370.

of this *Aphelinus* by the application of measures as we have mentioned.

"Berlese, in 1902, suggested the same method in the struggle against *Diaspis pentagona* (a scale-insect), one of the most dangerous enemies of the mulberry, in Italy.

"There still exists a method entirely different from that which precedes, but whose end is also to protect parasites and to assist in their multiplication. It consists in encouraging, or cultivating in the neighborhood of the plantations, wild plants which harbor them.

"Thus, for example, parasites of the olive fly do not live exclusively upon that insect, but also upon certain gall insects of the oak and the briar rose. Therefore, it has been recommended to preserve in the neighborhood of the olive groves bushes or hedges of these plants, or even to transport galls into the olive groves.

"Aside from the intelligent protection which should be given to beneficial insects and which, as we have just shown, can be based only upon exact knowledge of their biology and the relations which they have to other organized beings, can man assist in artificially multiplying them, and making of them a forced subject to his will which will serve him at will in the struggle against indigenous enemies of cultivated plants—those which for centuries have devastated our prairies, fields, orchards and forests.

"The fungous parasites and microbes have already been brought into our arsenal, from which we draw against the enemies of agriculture. Can we bring in entomophagous (insect-eating) insects in their turn?

"While they habitually accompany injurious insects wherever they are found, it may happen in a restricted region and an isolated plantation that the beneficial forms are absent, and there will be undoubtedly a benefit in introducing them. It often happens that coniferous forests are ravaged by insects without any of their most important enemies, such as *Calosoma sycophanta*. Will it not be opportune in such a case to transport a lot of these beetles from the region where they exist and acclimatize them in the devastated forests, where they have not appeared naturally?

"Then also with sedentary insects, such as the scale-insects, which develop often in closely circumscribed localities, it will be possible, when one chances to find a colony particularly invaded by parasites, to cut off certain branches and carry them into other orchards infested by scale-insects and less favored from the point of view of the presence of parasites.

"In 1871–'82, Le Baron, in the United States, made some experiments in the transportation of the small hymenopterous parasite *Aphelinus mytilaspidis* from one locality to another, attaching the branches covered by the parasitized scale-insects to infested trees which were found in a region where the chalcidid parasite did not exist. At the end of the year it was stated that the parasite had become domiciled in that locality.

"Johnson has noticed that another parasite very close to the

preceding, *Aphelinus fuscicollis*, may be extremely abundant in certain localities invaded by the San Jose scale, and be totally absent, on the contrary; in others, and he succeeded in propagating this insect by suspending upon a tree, at small distances, small baskets containing twigs covered with parasitized scale-insects."

Here the author digresses to say, and with him we fully agree, that however justifiable such practices may be in certain determined cases, in order to be convincing the greatest care and attention must be paid to every detail, and that under normal conditions the parasite is likely to accompany its host and the work of artificial distribution would in such cases be of no avail. He concludes:

"A more profound study of parasites and predaceous insects—of their development, their migrations, their geographical distribution—will show us without doubt and in a more precise way the real value of the consistent method to be used in transporting indigenous parasites, and thus assisting in their spread. In any event, it suffices to say that actually it appears applicable in a rather limited number of cases."

In 1897, L. O. Howard, of the United States Bureau of Entomology, in discussing the parasites of the white-marked Tussock-moth wrote:

"At points where the caterpillars are scarcer they are thus less exposed to the attacks of their parasitic enemies, and it results that there may actually be an increase of the species at one point simultaneously with a decrease at another. This, then, at once suggests that in a small way artificial transportation of the *Pimpla* in particular may often be of some practical benefit.

"It has been shown, for example, that *Pimpla inquisitor*, the most numerous of the parasites mentioned, is a very general feeder on lepidopterous larvæ, and in such cases as this extensive parasitism of *Orgyia* in Washington, if the right moment were seized, a surplus of the parasites could readily be sent to such points a Boston, where, perhaps, the species would be found to attack even the gipsy-moth, although, according to the reports of the gipsy-moth committee, this species has not as yet been reared from this host."

In January, 1908, in a bulletin on the parasites of the cotton-boll weevil, by the United States Department of Agriculture,[1] Prof. W. D. Hunter, in introducing this publication says:

"While the work of parasites, discussed in this bulletin, is not at present one of the most important factors in the control of the boll weevil, the indications are clear that its importance will grow rapidly. Moreover, the matter has special interest, for the reason

1. U. S. Dept. of Agr., Bureau of Ent., Bull. No. 73, January 21, 1908.

that it is not unlikely that practical means may be devised to increase the work of the parasites.

"There are two possible practical applications of the information obtained and recorded in this bulletin, both, however, requiring expert entomological knowledge and experience. These are (1) the propagation and collection of parasites, and their distribution in regions where the same species are either present in but small numbers or altogether absent, and (2) the elimination of related weevils by the destruction of their food-plants in or about cotton-fields, thereby forcing the parasites to transfer their attention to the boll weevil.

"Under the plan of artificial propagation, by picking large numbers of squares in fields where the weevil is highly parasitized and placing them in cages adapted for such breeding, large numbers of parasites might be obtained. The weevils should then be killed. These parasites could be released in fields with a low percentage of parasitism, and the results under favorable conditions should be apparent after one generation of the boll weevil. In this bulletin will be found an account of an apparently very successful experiment of this kind, in which, at Dallas, Tex., the percentage of parasitism was brought up to 9.1 per cent. by the introduction of parasites from Waco, about 100 miles away."

Mr. Pierce, the author of this bulletin, writes:

"Inasmuch as the parasites are known to attack the weevil in its first generation in a newly infested locality, it may be expected that by releasing the proper parasites in a given locality the percentage of parasitism may be increased in a very short time. Such a case was actually obtained by the release of *Bracon mellitor* at Dallas, as described in the section on propagation.

"The release of parasites in the field was not commenced until September 12 on account of the small amount of material gathered prior to that date. Notwithstanding that fact the results give an indication of success. On the laboratory farm at the top of the hill there were released thirty-five parasites on September 12 and thirty-nine on September 15. These parasites were of three species."

It is interesting to note that in the field-work on the release of parasites in this report there were three experiments using the three species, and the total in all sixty-two female and eleven male parasites. And although these were liberated in fields where these parasites were already known to be at work, the author, in his conclusion, says:

"Release of parasites in the open field on a small scale has been found to increase the rate of parasitization. This will be tried on a more extensive and better planned outline another year.

"The abundance of hosts which have parasites in common with the weevil, and the fact that parasitization takes place in the first generation, give promise that the weevil's advance may be constantly disputed by the parasites."

Regarding the efforts to control the gipsy and brown-tailed moths in New England by means of parasites, Doctor Howard wrote, in 1905:

"With the cessation of the exterminative measures instituted by the state of Massachusetts, and the indication of the probability that much can not be expected from native American species, it has become evident that one of the best hopes of lessening the damage done by these insects rests in the importation and establishment of the European parasites and other insect enemies."

For the fiscal year 1906, Congress appropriated not to exceed $2500, and Massachusetts $10,000 a year for three years, to be used in an effort to import parasites of these two moths. For Massachusetts, A. H. Kirkland was made superintendent, and he, with the consent of the Secretary of Agriculture, placed under the control of Doctor Howard a large part of the fund appropriated by the state of Massachusetts.

Now, as already expressed, it is the purpose in presenting this phase of the subject under the head we are discussing, to present only the opinions of others. Accordingly, the present status of the utilization of parasites in an endeavor to control the gipsy and brown-tailed moths is quoted from Marchal, already cited:

"The caterpillars of these two species are extremely common in Europe, their original home. They are injurious, and from time to time appear in great numbers. It is to be remarked that in a year following their large multiplication the caterpillars of these insects become rare and that they remain so for a long time. They are, then, very far from being responsible for damage similar to that which they cause every year on the other side of the Atlantic. With us their presence is tolerable, and they do not cause notice since they do not threaten the vitality of the trees. In Massachusetts, on the contrary, they constitute a permanent plague, which has commenced to invade neighboring states.

"The difference in these conditions appears to be that in Europe the insects are held in check by parasites, which are much more numerous than in the United States.

"Some American parasites have adapted themselves to destroying the gipsy-moth. There are five hymenopterous and six dipterous parasites, without counting several predaceous species which attack it. But this is small in comparison with the twenty-seven hymenopterous and twenty-five dipterous parasites of the gipsy-moth in Europe. While the parasites of the brown-tailed moth are less known, it is perfectly sure that in Europe this insect is kept in check much more efficaciously by its natural enemies than is the case in America. On account of these considerations it was only natural to seek to introduce into Massachusetts the original parasites of these two insects. For a long time it was not judged wise to undertake the enterprise. A law obliging the systematic destruction of the gipsy-moth and the use of insecticidal mixtures

seemed to render it inadvisable. Moreover, there was confidence in the fact that the native parasites would increase. Now the conditions have changed. In 1900 the appropriations were stopped, at a time when the insect was well in hand. In five years, however, it has spread over a territory four times as great as that which it occupied in 1900, and has commenced to spread in the neighboring states of New Hampshire and Rhode Island.

"On the other hand, in the thirty-six years that the insect had infested the country about Boston, American parasites, if efficacious, would have manifested it in an appreciable way. The same considerations applied to the brown-tailed moth.

"Americans resolved, then, to attempt a last great effort to master the plague against which a long struggle had given insufficient results. In the appropriation bill of the Federal Congress, in 1906, $2500 were appropriated to begin the importation of parasites of these two insects into the United States. At the same time the state of Massachusetts appropriated $10,000 a year for three years for the same end. A special superintendent, Mr. Kirkland with a staff of agents and assistants, was charged to preside over the execution of the work in America, and Mr. Howard, during the three years 1905, 1906 and 1907, was sent on a mission to Europe to seek for the parasites of the two species, visiting France, England, Italy, Germany, Austria, Hungary, and Russia. He interested in his enterprise all of the official entomological bureaus, as well as the principal specialists, who promised him their help and active coöperation.

"It is by hundreds of thousands that the nests of the brown-tailed moth have been sent to Boston for two winters. It is in innumerable quantities that, during the months of June and July, caterpillars and chrysalids of the two species have been sent to both destinations. All these insects upon their arrival in Boston, where they have been received by Mr. Kirkland, are sent to a laboboratory specially constructed for this work. It is in the suburbs of a small village named Saugus, in a house which is constructed in the midst of a wood infested by the caterpillars of the two species. Aside from the rooms devoted to research and rearing work, this house contains the local or resident assistant who has charge of the work, and also the specialists who are sent by the Bureau from Washington at the time when the insects are appearing. The insects are reared in boxes constructed for that purpose, and somewhat like those employed by the State Board of Horticulture of California. To avoid the issuing of hyperparasites or of suspected species not existing in America, and accidentally mixed with the sendings, the cages are kept in closed rooms with double doors. They are arranged side by side in several longitudinal rows, and so abundantly that it is difficult to walk between them. When issued the parasites are generally not set at once at liberty, but are allowed to breed in large outside cages.

"To what practical results will these experiments conduct us? It is difficult to answer this question in a decisive way. The ex-

periments have been in any case carried on under conditions most perfectly constituted to assure success of the enterprise, and it was impossible to confide their execution to a savant of greater authority than the eminent director of the Bureau of Entomology at Washington. Having a great number of parasites imported, an abundance of food which they find at their disposition, and a climate they will encounter analogous to that of Europe, it does not appear doubtful that many species will acclimatize themselves, and as soon as acclimatized they cannot fail to strongly influence the balance of nature to the prejudice of the destructive species.

"The time necessary for this movement of the seesaw may be long, and it seems that one could hardly expect appreciable results before four or five years.

"But what does this matter, in any event, since we are trying to obtain a result of indefinite duration which will bring about exemption from the ruinous methods of destruction by insecticides and which will mark the end of a public calamity menacing trees of the whole United States?"

Parasitism in General.—Parasitism is a condition which exists widely throughout the animal kingdom. Hunger and the quest for shelter have doubtless led to the habit of existing as unbidden guests in or on other insects or higher animals. The one, a parasite, lives in or on the other, a host, securing the necessities of life from the host. The host gives up a part or all of its vital force to the parasite. Very few species of insects are exempt from the entertainment of parasites. Parasites themselves are parasitized. Among insects are to be found all variations of parasitism—the external parasite, as the sheep-tick, or the bird-louse, external parasites spending the whole existence upon the host; the braconid fly, depositing its eggs upon the back of some other insect wherein the braconid larvæ or grub will dwell until pupation, then to emerge as a winged insect—an internal parasite for part of its existence. A case in point of this sort is a parasite—the *Lysiphlebus*—on the green bug. The advantages gained by the parasite are great—abundant food, safety, and warmth, all necessities of its natural well-being. There are, however, disadvantages. The parasite tends to degenerate through disuse of organs. The sheep-tick was once a winged fly, but since it spends its whole life upon the same animal its wings were no longer used, and consequently were less and less developed.

The group of insects to which this parasite of the green bug belongs shows very little of this degeneration due to the adoption of the parasitic life. Such are parasites for but part of their life, and for the rest they are extremely active and independent beings.

Parasitic insects that depend exclusively upon certain forms for

existence lay themselves liable to great reduction in numbers, even to extinction. This is likely to occur should their host become greatly reduced in numbers, either through attacks of the parasites themselves, or through other causes.

Among insects there are also some parasitic upon plants, and others are parasitic upon eggs of other insects. This subject of insect parasitism is of so great biologic importance as to be of vital interest to man himself. Insects primarily depend upon vegetation for sustenance. So rapid are their powers of assimilation and so prodigious their efficiency for multiplication that, were they to go on unheeded and unchecked, they would in the struggle for existence overcome mammals. Such is not the case, however. Insects are as a house divided, one part preying upon and destroying the other; the two succeed each other like wave upon wave. Parasites, finding innumerable insects to prey upon, increase so rapidly as to devour their means of support. They in turn succumb, and the host rallies only to be defeated again. So the struggle goes on forever.

(*b*) UTILIZATION OF PREDATORY SPECIES.

Nearly one-half of the highly injurious insects now present in the United States have been accidentally imported into this country. These species are not in all cases the most injurious in their own country, for the reason that there exists a natural and sufficient number of predatory and parasitic insects to keep the injurious forms in check. After accidental introduction to this country, they usually find large areas of their favorite food-plants, and with few enemies to keep them in check soon become a menace to the crops upon which they feed. And so America has taken up the work of fighting the insect enemies of agriculture by means of their parasites and predatory enemies. In the case of these imported insects, it is obvious that these allies of agriculture must be looked for in the native country from which the injurious species came.

By far the most noticeable illustration of this method of insect control is that brought about by a small ladybird beetle, introduced first into this country to combat the fluted scale. In 1888 the entomologist Koebele, under recommendation of the Government Division of Entomology and at the expense of the California fruit-growers, was sent to Australia, the native country of the fluted scale, to find and send back some effective predaceous or parasitic enemy of this scale, so destructive to citrus industries. Altogether about 500 Vedalia ladybird beetles in five separate lots were brought from Australia and placed on trees infested by the fluted scale.

This work as it now stands is called by Prof. Paul Marchal, of Paris, "An unprecedented triumph against one of the most redoubtable enemies of cultivated plants." And since this writer's narration is recent and in detail, it will be here recounted.[1]

"THE USE OF THE LADYBIRD BEETLE AGAINST THE FLUTED SCALE.

"The fluted scale is a scale-insect living upon different trees, and particularly upon citrus trees. It is originally from Australia, and was accidentally introduced, about 1868, into California, where it did enormous damage and threatened to ruin the cultivation of oranges and lemons. All attempts to fight this Australian insect with different insecticides were vain. It continued to spread in a progressive manner from the orchards that had already been annihilated or were in bad condition.

"Riley, then director of the Division of Entomology of the Department of Agriculture, at Washington, thought of utilizing the natural enemies of the scale-insect. Ascertaining that in Australia, its original home, it did not seem to be seriously injurious, and to be without importance from the economic point of view, he was led to think that it was probably held in check there by parasites. Investigations which he made on this question having confirmed his ideas, he made every effort to accomplish the desired end, namely, the acclimatization of the natural enemies of the fluted scale in California. Finally, after numerous appeals to the government, he was able to arrange for a sending of two agents of the Division of Entomology to Australia on the occasion of the exposition at Melbourne, in 1888, with a credit of $2000. One of these agents, Mr. Koebele, was especially instructed to search for parasites of the fluted scale.

"On his return he brought a collection of the natural enemies of the Australian scale-insect. Among these there were a hundred living specimens of Vedalia ladybird beetle. It multiplied so rapidly that in the following year, 1889, they could distribute to the fruit growers of California 10,000 specimens. A year and a half after its introduction it had relieved the region from fluted scale and had reduced their number to a practically negligible quantity. According to witnesses this deliverance possessed for the inhabitants of the country an almost miraculous character. Immense groves of oranges bearing no fruit, covered with a horrible, white leprosy composed of the fluted scales and which seemed irremediably lost, suddenly took on a new vigor and furnished abundant crops. Now the only natural means necessary to hold fluted scale in check consists in sending a small number of ladybird beetles to start colonies in the district where the scale-insect shows a tendency to regain its foothold. In this way reserves of ladybird beetles are constantly kept on hand for exportation, either to the different districts of the state of California or to foreign countries, and the State Board of Horticulture of California has constructed small boxes of glass and wire gauze of octagonal form, sixteen feet in

1. *Popular Science Monthly*, April, 1908, pp. 363-370.

diameter and eighteen feet high, allowing the fluted scale and the ladybird beetle to live upon the trees surrounded in this way.

"In 1894, at the opposite extremity of the United States, in the state of Florida, a new invasion of fluted scale was produced, and the scale-insect was introduced, this time under conditions which show very well the risks attending such attempts to acclimatize useful insects when they are made by incompetent persons. A nurseryman in Hillsboro county, Florida, having heard of the extraordinary services rendered by the Australian ladybird, being ignorant of the fact that this insect will not attack other insects than the fluted scale, sent to California for the ladybird beetle to fight the *Aspidiotus*, or other scale-insects, feeding upon their plants. The ladybird beetle was naturally sent with some fluted scale which would serve as food for it on the journey, and they were all placed together by the nurseryman upon the trees which he desired to protect. No one knows what became of the ladybird beetle, but the fluted scale multiplied and was not slow in covering the trees upon which it had been placed. Radical measures were almost immediately taken; all the trees attacked were burned; and for four years nothing was heard of the insect. It was believed to have been entirely exterminated, but in 1898 the presence of specimens of fluted scale was discovered. The formidable scale-insect was found at this time at several points near the locality where it had been first imported, and it had invaded one or two orange groves. It was necessary to give up all hope of exterminating the species, and an immediate effort was made to introduce the ladybird beetle.

"Mr. Gossard, state entomologist of Florida, and Mr. Al. Craw, entomologists of the State Board of Horticulture of California, directed the work. The ladybird beetle was at first colonized with success in two of the infested orchards, and in 1900 had become sufficiently well established to enable them to distribute it in good numbers in infested localities. It seems to be certain that the fluted scale finds in Florida conditions less favorable to its development than in California. It has been stated that it is attacked there by a fungous disease. In any event, it cannot be doubted that with the assistance of the ladybird beetle it will never play in Florida the injurious role which it has played on the Pacific coast.

"America is not the only country which has suffered from the introduction of fluted scale. This insect has been imported, or was imported at almost the same time, into South Africa; and more recently it has made its appearance in the Sandwich Islands, in Portugal and in Italy. The Vedalia ladybird beetle has in these cases been sent for, and the success has been as complete as that obtained in California. The history of these successive invasions and of the efforts which have been made to combat them conveys useful instruction and is worthy of our attention.

"*Vedalia Ladybird Beetle and Fluted Scale at the Cape.*—About 1890, fluted scale having been at the Cape already for some years a great subject of alarm, the secretary of agriculture, at Cape-

town, made an effort to secure the ladybird beetle from Australia and from New Zealand, but the correspondents to whom he wrote had not been able to collect a sufficient number to make a sending, and a demand was made upon the Department of Agriculture of the United States. Following the year 1891 an ample provision of larvæ and pupæ was sent from California to the Cape. But on account of the length of the voyage no living specimens arrived. At the end of the same year Mr. Thomas Low, member of the legislative assembly of the Cape of Good Hope, went to the United States, charged by his government with a mission connected with different agricultural questions, and notably to secure the sending of the ladybird beetle. He procured three boxes full of this insect, and left New York the 23d of December, 1891. One of these boxes was placed in the ice-box of the steamer. He kept the two others in his cabin, feeding the ladybird beetle regularly during the journey with fluted scale. The three lots, including those preserved in the ice-box, arrived in perfect condition, and on the 29th of January were placed in the hands of the secretary of agriculture of the Cape.

"The insects were then utilized in the following way: A small number were placed in the open air upon an infested tree in the botanical garden in Capetown; but the majority were used for rearings in captivity. Some were placed upon an infested orange tree which was surrounded by a great wire-gauze cage, while others taken to a different locality were placed in a sort of glass house constructed around the orange tree, and similar to those used in California for the same purpose.

"The efforts destined to naturalize the ladybird beetle in South Africa were reinforced about the end of 1892 by a new sending coming from Australia, and sent by Koebele, who was then on a mission to that country.

"To-day the ladybird beetle is perfectly naturalized at the Cape. In some spots which are particularly exposed to cold and where the winter is very vigorous, they succumb to the low temperature, and the entomological service is obliged to frequently renew the colonies. This, however, is exceptional, and almost everywhere the ladybird beetle, perfectly acclimatized, holds the fluted scale in check so efficaciously that since several years they have not worried about it.

"*Icerya ægyptiaca and Ladybird Beetle in Egypt.*—About the same period several attempts were made to introduce the ladybird beetle from California into Egypt, not to fight fluted scale, but an allied species, *Icerya ægyptiaca*, which is of unknown origin and for several years had been found in the gardens of Alexandria, where it did great damage to the oranges, lemons and figs. The first attempts failed on account of the length of the voyage, but a new attempt made about the beginning of the year 1892 was crowned with success. Six adult insects and several of the larvæ arrived in living condition at Alexandria. They were set at liberty upon an orange tree infested with *Icerya ægyptiaca*, and accommodated themselves so well to this new food that in a short time

they had become so numerous as to cause an almost complete disappearance of the *Icerya*. But later the *Icerya* again began to increase. Happily, however, the ladybird beetle had not entirely died out, and it also recommenced to multiply, and, thanks to the successive seesaw movements between the two species, the *Icerya* is held in check in a definite way.

"*Fluted Scale and Ladybird Beetle in the Hawaiian Islands.*—In the Hawaiian Islands the alarm provoked by the invasion of fluted scale was of short duration. The injurious insect was discovered in 1889 in the suburbs of Honolulu, and multiplied there with rapidity. In 1890 the ladybird beetle was in its turn introduced from California, and a year afterward the trouble was entirely stopped.

"*Fluted Scale and Ladybird Beetle in Portugal.*—In 1897 the presence of fluted scale was discovered in the orange groves around Lisbon, and the agricultural population began to be alarmed. This insect had multiplied already for several years along the banks of the Tagus river, and it seemed that the first infested plants had been brought from the Azores, where for a long time the Australian scale-insect had existed.

"In 1897 almost all the gardens of Lisbon and its suburbs were infested with the fluted scale, and the insect was known to occur in thirty-two localities. Before attempting the introduction of the natural enemies, the Australian insect, they tried insecticides, which were found insufficient to stop the scourge, but which, nevertheless, were of much service from time to time, when it was deemed desirable to introduce the ladybird beetle. Messrs. de Silva and Le Cocq were particularly interested in this latter matter. In spite of a hostile press and the opposition of the greater part of the administrative authorities, they placed themselves in relations with Mr. Howard, the learned director of the Bureau of Entomology of the Department of Agriculture of the United States, and he wrote to San Francisco, to the State Board of Horticulture of California, and procured from Mr. Alex. Craw sixty ladybird beetles in the adult condition, as well as a certain number of larvæ in different stages of development.

"As soon as they arrived in Washington, in October, these insects were placed in boxes with moss with an ample supply of fluted scale for food, and were then sent on to Lisbon. The greater part of the ladybird beetles perished on the voyage. Five only, coming from larvæ which transformed on the journey, arrived alive at their destination. On their arrival they were placed in breeding-cages at the Experimental Agricultural Station of Lisbon, and were cared for in such a fortunate way that in the month of December they had already a numerous progeny.

"On the 22d of November a second colony of ladybird beetles were sent to Lisbon. The journey this time, on account of accidental delays, was particularly long, and from San Francisco to Lisbon it lasted no less than forty-four days. Five females and one male still lived on arrival, and these received the same care as the

others, and the success was such that in June, 1898, these six samples received in December, 1897, had several thousand descendants. On account or the danger to which we are exposed of sometime seeing the orange groves of the south of France and the north of Africa invaded by fluted scale, we believe that it will be useful to give some details of the methods used in breeding under the direction of M. Le Cocq. (See pp. 32-37, Bulletin 18, new series, U. S. Dept. Agr, Div. of Ent.)

"This method of work, which permits the handling of the ladybird beetle without touching them, has been practiced in Portugal on a large scale, and thanks to this method, they were able to obtain an immense multiplication of the Australian ladybirds; but in order to facilitate the rearing still more and to obtain as great a production as possible, they constructed a large wire-gauze cage after the model already used in the United States.

"In 1898 thirty-eight centers of dispersion, in Lisbon and in the suburbs, had been thus established and were in active operation. In the month of August 90 colonies existed; in September 487, without counting the secondary colonies started by the orchardists themselves, who had given one another specimens of these precious insects.

"The gardens and orchards, which were completely infested and almost ruined, were cleaned of the scourge as if by enchantment. The number of fluted scale became practically negligible, and all treatment with insecticides was from that time entirely superfluous. In a letter addressed at this time to Mr. Howard, Mr. Le Cocq wrote as follows:

"'The multiplication of the ladybird beetle which you sent in November and December has been astounding. . . . The result exceeds everything that we could reasonably expect. The colonies of ladybird beetle are now being distributed profusely every day to many farmers and gardeners who ask for them, and you must not doubt that we recognize their value and appreciate the exceptional service you have rendered to Portuguese agriculture and horticulture.'

"However happy these results, it should not be forgotten that the ladybird beetle, in Portugal as well as elsewhere, has not been able to completely exterminate the fluted scale. It keeps it from reaching the condition of a pest, but it is not able to prevent its dissemination or its slight increase. Mr. Duarte d'Oliveira, Oporto, to whose kindness I owe certain interesting documents upon the history of fluted scale in Portugal, has written me that he has recently found several colonies of this insect in the north of the kingdom, in the province of Traz-os-Montes, where it had previously made its appearance.

"*Ladybird Beetle and Fluted Scale in Italy.*—The fluted scale was introduced accidentally into Italy at the end of the year 1899 or in the spring of the year 1900, without any indication of the origin of the infection. But it was observed for the first time, in the month of May, 1900, at Portici, near Naples. It was there found

in a little garden upon orange trees, and was represented only by a rather small number of individuals. The proprietor of the garden, ignorant of the character of the insect and of the danger arising from its presence, took no trouble to destroy it, and the scale-insect, able to develop freely without enemies, spread so rapidly that in the autumn it already covered the bark and leaves of the oranges upon which it had first been observed. Startled at this sudden invasion, but not yet deciding to apply to competent persons, the owner of the garden tried to stop the trouble by cutting down the most infested trees without bothering himself with those that were not badly infested; so the infestation continued The 18th of November the same year, the entomological laboratory was notified of the occurrence; and Professor Berlese, the director of the laboratory, recognized the species as fluted scale. The insect was still very localized, and it was found at this time only in the adult condition in the little garden which was the center of the infection, and upon a large bay-tree, which occurred in another neighboring garden, occupying a high position, and whose branches overhung the infested garden. This bay-tree, on account of the strong winds which blow at that time of the year, constituted a center especially favorable to the dispersion of the larvæ into the surrounding trees; and, in fact, the larvæ were found in all the little gardens about. An examination was made and it was found that the infested area did not exceed one hectare.

"On account of the small spread of the insect they tried to exterminate it by an energetic application of insecticides. The first thing done was to cut down the bay-tree, which was the principal center of diffusion, and to burn it after having cut off and disinfected all the branches bearing leaves. In the infested gardens all the affected trees were cut back and all the branches were disinfected with a solution of rubina. The low-growing plants were treated with sprayings of the same insecticide. They hoped to rid these of the insects in this way, but in the following spring living larvæ, still very numerous, were found crawling over the plants treated, and then, despairing of destroying them with insecticides, they had recourse to ladybird beetle. At Professor Berlese's request successive sendings were forwarded from Protugal by Mr. A. Le Cocq, director of agriculture, and by Mr. L. O. Howard, director of the Bureau of Entomology, of Washington. With the assistance of the material thus obtained it was possible to make at the entomological laboratory, at Portici, a methodical rearing of the beetles. Different methods were employed, and on June 9 the first distribution of ladybird beetle, of both sexes, was made in the garden which had been the center of infection, the fluted scale having made rapid progress and the garden being again infested by legions of fluted scale.

"June 28 other similar distributions were made in the other neighboring gardens.

"The insects prospered marvelously, rapidly seeking the fluted scale wherever they could find them. It should be remarked that

the ladybird beetle, once acclimatized in a region, knows very well how to find trees attacked by fluted scale, even when they are some distance away. Therefore it is not absolutely necessary to distribute them to all points. In July the results were already evident. One could hardly find patches of fluted scale which did not show the work of ladybird beetles, and at the end of the month it was difficult to find adult fluted scale with which to continue its breeding in the laboratory to afford food for the ladybird beetle. By the end of autumn there was only here and there a rare individual that had escaped the massacre. In 1902 the intensity of the invasion was entirely minimized, but under the influence of the winds the area of dispersion extended to about a kilometer. Very fortunately the ladybird beetle, which had become very rare, reappeared. According to information very obligingly sent to me by Mr. Leonardi, of the laboratory at Portici, they still continue to-day to fill in a marvelous way the role which devolves upon them, and their naturalization can be considered an accomplished fact. This single fact alone indicates, without any need of further evidence, that they have not exterminated the fluted scale.

"If they have reduced the multiplication of the insect to the point of rendering it practically negligible, it is none the less true that the original infestation persists, and that the area of distribution of the scale-insect is slowly enlarging.

"The fluted scale is met with to-day not only at Portici, but in all the little towns around Vesuvius, and all the gardens of Naples have it in greater or less quantity. It is probable that the area will always exist about the first locality. If the beneficent ladybird did not exist by the side of the scale-insect, the culture of oranges and lemons would be seriously interrupted, and in a few years throughout the whole Mediterranean region."

THE SOUTHERN GRAIN APHIS.

Toxoptera graminum.

COMMONLY KNOWN AS THE GREEN BUG.

The insect is one of the many species of plant-lice. In structure and classification it is allied with the chinch-bug, box-elder bug and the familiar cicada or harvest-fly. All of these feed not on plant tissues but on plant juices extracted by means of a well-adapted tube or proboscis. Size and color are the readily noticeable differences among plant-lice.

In order to learn of the behavior of the green bug in Italy, where it first came into prominence, a letter of inquiry was directed to Doctor Berlese, director of the Royal Station of Agriculture at Florence. The reply as translated was submitted to its writer, and with his kind permission it is now published.

"ROYAL STATION OF AGRARIAN ENTOMOLOGY,
FLORENCE, November 25, 1907.

"ESTEEMED PROFESSOR—[1]At the request of the director, Professor Berlese, I am answering your esteemed communication relative to *Toxoptera graminum* Rond.

"The first man to give attention to this species in this country was the (late) lamented Professor Rondani, the well-known dipterologist of Parma, who wrote about it in 1852 (Annali delle Scienze naturali—Annals of the Natural Sciences, Bologna), when in June the appearance of the winged females was so great in all northern Italy as to form large groups like clouds in the air, not without annoyance to people either, and so great as to cover afterwards with their remains the streets of the city.

"Since that year there has never been a similar appearance observed, although it has often been found sufficiently numerous in the various regions of the central and northern part, particularly in the peninsula, as to cause noticeable damage to broom-corn (*Sorghum saccharatum*), to corn (*Zea mays*), and to wheat (*Triticum sativum*), rather than to barley (*Hordeum vulgare*), and to oats (*Avena sativa*), to say nothing of the Gramineæ of the meadows and pastures, *Lulium*, *Bromus*, *Dactylis*, etc.

"Among these same plants, as far as I have seen, the insect passes its life pursued by the *Aphidius*, by the *Syrphus*, and by the *Coccinella*, and so forth, less than by the Entomophtoreæ (*Entomophtora aphidis*), and largely followed by *Tetramorium* and other ants, which have no less importance in the life of the *Toxoptera* than they have in other species of aphids.

"The *Toxoptera graminum* (Rond.) Pass. is a species most abundant and largely represented on the plains and in the bottoms

1. Translated by Mr. ALFRED D. SCHOCH, of the Department of Romance Languages, University of Kansas.

FIG. 19. *Toxoptera graminum.* Migrant form, feeding on wheat-stalk. From photograph, enlarged. (Original.)

of the valleys, rather than on hills, where it is extremely rare in this country, and in the mountains, not having ever found it, I am about to conclude that it is wanting there almost or entirely.

"In small, detached fields of broom-corn and wheat I have noticed that it frequents particularly and is most abundant on the plants situated along the draining-ditches and along the furrows that cross the fields rather than near the rows of plants which are there when they are cultivated "a corona" (= trimmed), perhaps on account of the coolness of the ground late in the season, while from the beginning the signs of its presence have an undoubted connection with the nearness or presence of the other Gramineæ, wild or cultivated, on which the species has lived after the death of the annual species, to which it returns at the beginning of the next spring.

"Given thus a very summary idea of what happens with the species in relation to its known sustaining plants, for protection against it I will say that when it has been necessary it has seemed to me an adequate measure to apply to the soil-fertilizing substances of ready assimilation so as to favor the vegetal growth and have plants capable of producing a crop in spite of the presence of the aphids.

"For this and for other infections of plant-lice, always on the Gramineæ, I have also indicated the means of insecticides, but given the nature of the plants and the way in which they are cultivated, such a proceeding cannot be considered unless it is to suffocate the first centers of infection where they occur, so that it may not spread further around. So, also, to hinder the passage of the insect from the spontaneous plants or those of the meadows to those of the fields, I consider it advisable to proceed against these plants all over the cultivated ground with work with suitable farm implements, and then on the strips of natural pasture or meadows, where the presence of the louse may have been observed, before the latter provides itself with wings, with the means that seem adapted to the case.

"I have the honor of sending you with this letter a printed notice in which you may find a description of the insect in question.

(Signed) GIACOMO DEL GUERCIO.

Professor of Agrarian Entomology in the Superior Institute of Florence."

TOXOPTERA GRAMINUM ROND.

The wheat *Toxoptera* recalls in the forms of its body *Toxoptera* of the citrus trees, from the reproductive wingless female from which it is distinguished because it is of green color, while biolog-

ically it recalls to mind the *Siphonophora* of wheat [*Macrosiphum granariæ* (Kirby) Pass.]

The infection on the part of this louse, therefore, comes upon the grain, especially upon corn (maize), on cane and oats, by means of the reproductive winged females, which are developed on the cockle weed (*Lolium perenne*, etc.), at the base of which and other wild Gramineæ the wingless reproductive forms are found sheltered at the beginning of spring.

The leaves of plants occupied by the louse turn a rusty color and afterward fall off, for which reason the crop may be considerably decreased where the infection becomes serious.

As for the *Siphonophora* of wheat, so is the direct defense against this louse also quite difficult; so much so that it is still necessary to resort to indirect means, which tend to produce more advanced and robust plants, as I have indicated for the *Macrosiphum* of wheat, proceeding at the same time where possible against the wild Gramineæ, which for a double reason turn out infected in the sown fields.[1]

IN THE UNITED STATES IN 1907 AND 1908.

The accompanying map (fig. 11*a*), as prepared by Sanborn, designates the place of the earliest serious infestation. From this point migration outward, and especially northward, took place. According to Webster this insect was found in 1907 "from Colorado and New Mexico to the Atlantic coast; approximately covering the area south of latitude 41 degrees and east of longitude 105 degrees." It was also found scatteringly outside of these boundaries.

IN KANSAS IN 1907.

The first instance of this insect in Kansas was found in December, 1906, by Sanborn, near Girard, Crawford county. Sanborn had collected and studied the Kansas insects of this group since 1902, and as this is his first record upon this insect, it would seem that this might be considered its first appearance in Kansas.

Spring Season of 1907.— During the spring it was present in every wheat-growing county of the state. Obviously it was more abundant in the southern part. Here in places fields of small grain seeded without proper attention to the essentails of successful grain production showed the effects of this insect. As stated in the introduction, alongside such fields were to be found satisfactory yields of grain, a forceful object-lesson in proper seeding and tillage.

1. Estrallo dul Bollettino ufficial del ministuero di agricultura industria e commercio, 1906, pp. 12, 13.

FIG. 20. Parasitized "green bugs" on stalks of growing wheat. Slightly reduced in size. From photograph. (Original.)

Fall and Winter Seasons.—With such a general distribution of an insect in the spring it is of great importance to know how it fares during the summer, amidst its own enemies and during a period of absence of its propitious food-plants.

Throughout the early fall there were many reports regarding the appearance of green bugs from many localities of the state. When verified, however, they proved to be cases of mistaken identity. Later, however, in following out one of these reports, a package of true green bugs was received on November 7 from Mr. Rogan, Olivet, Leavenworth county. In this package there were 1309 green bugs, 188 of which were parasitized by the parasite *L. tritici* —more than fourteen per cent. These bugs were isolated on growing wheat, and on the 20th all were parasitized. Glenn visited this locality on the 14th of November. In an eight-mile drive north from Leavenworth to Mr. Rogan's home, fields of wheat examined along the way revealed no green bugs. The south part of the wheat-field from which the green bugs had been received yielded an oats crop the previous spring, and the north part a millet crop. Stalks of volunteer oats a foot high were growing in the south part of the field. Green bugs were found only in that part of the field where oats stood.

"The south side of the field sloped to the south. Part of the west part of the field sloped towards the north and west and was bordered on the west by timber and blue-grass. A draw beginning about the middle of the field and running east gives to part of the east side of the field a north slope and to part of it a south slope.

"The bugs were found in greatest abundance in that part of the field on the west which slopes toward the west and north and is protected on the west by timber. Mr. Rogan stated that at first this was the only place he found them; then followed a high wind from the northwest and scattered them to the southeast. They were not scattered uniformly over this part of the field but were in spots. These spots looked to me to correspond nearly to the location of the shocks of oats, but Mr. Rogan said that they did not so correspond. In these spots the wheat was nearly all killed out, while on the plants between the spots only an occasional bug could be found. These spots were not more than a rod in diameter and were from three to six rods apart.

"I traced the bugs toward the south till I came to the south slope. I found no bugs on the south slope.

"Toward the east the bugs were found over the crest of the hill on the east slope, and also in small numbers along open furrows on the north slope of the eastern part of the field.

"The weather was cool and rather hazy. The thermometer ranged from 26 degrees F. at eight o'clock in the morning to 46 degrees at one o'clock in the afternoon.

"My investigation was made from ten to twelve o'clock. At ten the thermometer was 39 degrees and at eleven 41 degrees. The bugs were active and jumped from the plants at the least disturbance. It was difficult to collect any of the live bugs, or to make any satisfactory counts to determine the percentage of winged forms and of parasitized bugs.

"A small per cent. were winged, a much larger per cent. were parasitized—perhaps twenty or twenty-five per cent., taking into account the dead bugs and the large number of live bugs which were turning yellow. I saw no parasites active in the field, and the number of dead bugs from which the parasites had emerged was comparatively small.

"Earlier in the morning I examined a field on an adjoining farm on the north. This field had been in wheat the year before. Careful search in all parts of the field failed to disclose any bugs. Later I also examined a field lying west. Part of this field had been in wheat the previous year and part in oats. The part that was in oats was a south slope. No bugs were found in any part of this field.

"In the afternoon three fields of wheat on the north were examined. These fields where in corn and wheat the year previous. No green bugs were found. Another field, two miles east, also in wheat the previous year, revealed no green bugs. Next day found green bugs in small numbers in a wheat-field planted on oats ground located one mile south of Rogan's field. Parasites present and there were bugs only on north slope." (From Glenn's field notes.)

On December 11 a package of green bugs was received from I. S. Owens, having been collected from the farm of L. D. Langley, about four miles southwest of Oskaloosa, Jefferson county. On the 13th Glenn began an examination of this locality. A light

snow covered the ground, but the first field examined showed a number of green bugs present in a space of four or five rods. Parasites were present but none were active. The bugs were on a westerly slope. Volunteer oats were also in the field.

The next field examined, a quarter of a mile south, with no volunteer grain, and in wheat the year previous, showed no green bugs. About a mile west another field of volunteer oats contained an abundance of these insects. Some of the smaller plants were literally covered. They were much more abundant on the north slopes of this field. Parasitized bugs were also present. About a quarter of a mile west of this field was another with volunteer oats in the wheat. Here too green bugs were unusually abundant. This field belonged to Mr. L. D. Langley. Although the thermometer was only 33 degrees, the bugs were very active in getting off of the plants when attempts were made to collect them. Examined a number of other fields in this vicinity, none of which had volunteer oats growing, and found nowhere any evidence of green bugs. Looked carefully for eggs wherever green bugs existed but found none. The temperature during the day at this time was from 32 degrees in the morning to 33 degrees in the afternoon.

IN KANSAS IN 1908.

On January 6, 1908, Glenn and the writer went to the Langley field in Jefferson county. The temperature stood at about 48 degrees. The day was cloudy and there was an occasional drizzle. We found the bugs more abundant than they were the last time. We counted as many as forty-two on a single leaf. The wheat was apparently killed out in spots. It was raining when we were in Mr. Barnard's field, one-quarter of a mile from Langley's, and we were not able to go over the entire field. We did not find the bugs very abundant. On the way from Perry to Langley's we examined ten fields, but no green bugs were found anywhere. From both the infested fields we collected a large number of green bugs and brought them home. Out of 211, counted as they came, 23 were parasitized, so it seems that at this time about ten per cent. were parasitized. Before leaving Langley's arrangements

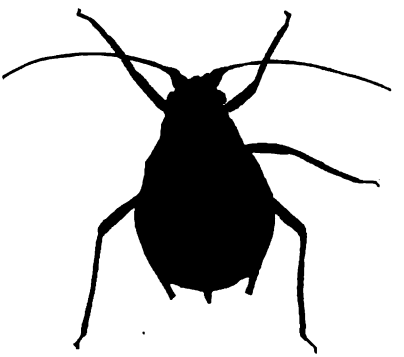


FIG. 21. The European grain-louse, *Siphocoryne avenæ*. Wingless form. A common wheat aphis. Greatly enlarged. From photograph. (Original.)

FIG. 22. *Macrosiphum granaria.* The English grain-louse, wingless form, a common wheat aphis. Greatly enlarged, from photograph. (Original.)

were made to have material shipped to us from time to time. An analysis of these shipments is as follows:

January 29, 1908.—Received specimens of wheat from L. D. Langley, Oskaloosa, Kan. Counted carefully over half of the material. Found the following:

Live green bugs	227
Adults	53
Young	174
Winged	4
Parasitized green bugs	30
Live parasites	1
Dead	1
Macrosiphum granaria	8
Siphocoryne avenæ	3

Per cent. of bugs parasitized, 13.

February 7 and 8 Glenn, on a personal examination, reports:

"I spent the afternoon of February 7 in Mr. Langley's field, from 2 to 5:30 P. M. The temperature at 2 o'clock was 65 degrees and at 5 o'clock 59 degrees. The sky was hazy and a moderate breeze was blowing from the southeast.

"I estimated that there were not more than fifty per cent. as many green bugs present as there were the time I accompanied Professor Hunter, on January 6. I examined the south end of the field more carefully than at any former time, and while I found bugs nearly every place, they were few in number, and parasitized bugs were very scarce. In the north part of the field the wheat looked thinner than before. This was due partly to the work of the bugs and partly to the fact that the drill marks had been partially filled by

the loose soil of the ridges blowing in. Many of the bugs were also covered up. In no case did I find more than a dozen on a plant.

"I found from one to five dead bugs around every stalk; some were on the ground, some covered by the loose soil which had blown into the drill tracks, and others were clinging to blades, mostly low down. These dead bugs were dark and shriveled, and had no doubt died from the effects of the cold weather which had occurred previous to our visit.

"About five o'clock in the afternoon I found two live female parasites. They moved about slowly and seemed to be feeding. I watched them for about twenty minutes. One did not come near any green bugs in that time. The other walked about among three green bugs but seemed to be hunting for something to eat, rather than for a chance to oviposit. I marked the place and returned the next day but did not see either of them. When I first saw them they were on plants about one and one-half feet apart.

"I spent Saturday forenoon in Mr. Barnard's field, and went all over his field to determine the extent of the infestation.

"The north side of his field had been in oats the previous season. A strip on the south side of this oats-field had been in white oats. Mr. Barnard told me that this ripened about ten or twelve days later than the other oats. It was in this strip that I found the green bugs. The west half of the strip slopes to the northwest. On this slope the bugs were not so plentiful as they were on the 14th of December, when I first visited the field. I found many dead bugs here also. The east end of this strip sloped to the east. They were more plentiful on this slope than in the west end of the field, but the wheat did not show the effects of their work so plainly.

"South of this strip was another strip about fifty yards in width. This strip had been in millet. I found no bugs in this field.

"Mr. Barnard told me that he had finished plowing before the middle of August and planted about the middle of September."

March 2, received from Mr. L. D. Langley, of Oskaloosa, Jefferson county, Kansas, package containing green bugs.

Number of green bugs	24
Parasitized bugs	0

Placed them on growing wheat. March 5 one green bug died, being parasitized.

March 28, Glenn went to the home of Mr. L. D. Langley, of Jefferson county, and examined his wheat; also the wheat of Mr. Barnard.

"After a search of about two hours I found four live green bugs in Mr. Langley's field, and three parasitized bugs and occasionally an *M. granaria*. I found no green bugs in Mr. Barnard's field.

"Mr. Langley stated that when he collected the material sent on March 2 he had much difficulty in finding them. I could not find any traces of the bugs which had been so numerous."

From the foregoing it would seem that the volunteer oats were

an important factor in making the existence of the green bug possible during this period; that north slopes, away from the strong July sun, were the spots favorable to the existence of this insect at this period; that the parasites, contrary to supposition, did work through the winter.

Status, March 30, 1908.—Ever since last spring, when the University of Kansas was asked by the millers, grain men and farmers to take preventive measures against the insect now commonly known as the green bug, this institution has, through its Department of Entomology, endeavored to keep in close touch with the situation in regard to this insect in Kansas. Accordingly, last fall, the University discovered the presence of this insect, first in one locality, and then in another in an adjoining county, both remote from the larger wheat areas. Here, as was demonstrated at the time, the existence of the green bug was made possible by the growth of volunteer oats allowed to stand to sustain the insect until the wheat appeared above the ground. Up to the present time this insect is not known to exist elsewhere.

Its behavior in this vicinity, however, and its present status in this state, are matters of importance, and the University is being plied with numbers of inquiries on this subject. When first found and for some time thereafter it developed rapidly in one field, so that early in January the insects were so numerous in places that in one instance forty-two were counted on a blade of wheat only one inch long. At this time 10 per cent. of the green bugs were parasitized. A month later, or about the middle of February, another examination showed that from 13 to 15 per cent. of the green bugs were parasitized.

The farmer upon whose place the insects were most abundant wrote the University asking whether or not he should plow up his wheat. Following the advice of the University in this matter, the farmers in this vicinity did not plow up their wheat, but allowed it to remain, for, as set forth to them, it seemed reasonable that plowing under would destroy their friend the parasite as well as their enemy, the green bug. This procedure seems to have been eminently successful, since on last Saturday a careful examination of the field by Professor Glenn revealed, after two hours of diligent search, only four green bugs, and these in a locality where they were most abundant last January.

The University has received a number of samples of wheat from different parts of the state containing an insect which by the casual observer might be mistaken for the green bug. It is not,

however, the green bug, but an insect that belongs to an entirely different genus, the green bug being known to science as *Toxoptera graminum* and this one as *Macrosiphum granaria* (fig. 22). The green bug, it is well known, made its first appearance in Kansas a little over a year ago, while this common wheat-louse is not of unusual occurrence and has thus far caused little or no concern. All reports concerning the green bug thus far verified by the University have proved not to be the green bug, but this common wheat-louse.

While these two insects are similar they can be distinguished by the color of the tubes extending horn-like backward from the end of the body. In the green bug these tubes are the same color as the body, being darker only at the tip. In the common wheat-louse, which is being so commonly mistaken for the green bug, these tubes are shiny black.

Of paramount interest, however, is the fact that as far as known, during the supposedly favorable mild winter just passed, the green bug, contrary to general belief, has not held its own but has been rapidly disappearing in the very restricted locality where it was present last fall.

SANBORN'S REPORT FOR 1908.

"*Points in Kansas.*—Between March 26 and April 3, at Wellington, Halstead, Newton, Great Bend, Winfield, Wichita, Arkansas City, and points northeast in Kansas, I found not more than an average of two or three green bugs in a half day's drive.

"*Points Outside of Kansas.*—At Wichita Falls, Vernon, Chillicothe, and Quanah, Tex., I found not more than an average of two or three green bugs in a half day's drive from March 24 to 25, inclusive.

"At McKinney, Tex., I found no green bugs, but noticed that the red rust was prevalent in the wheat-fields.

"Conditions at Altus, Clinton, El Reno, and Kingfisher, Okla., were about the same as at Wichita Falls, Vernon, Chillicothe, and Quanah, Tex.

"At Enid, Okla., several green bugs were present. In some fields I judge that a few brown spots will occur, due to a possible increase of the bug. At Blackwell and Ponca City I found conditions similar to those in Kansas."

This trip was begun March 22 and finished April 10.

The only other point outside of Kansas from which green bugs were reported in 1908 was in New Mexico.

On April 7, 1908, Mr. W. K. Folks brought to the department a small number of green bugs received from Lakewood, N. M. Upon request a larger number was received from Mr. Fred Vanderwork, of the same place, where it was stated they were increasing very fast on oats.

SOME EXPERIMENTAL STUDIES.

LIFE-HISTORY OF THE GREEN BUG.

Thus far we have been unable to find or to rear the form commonly known as the stem mother, the one which emerges from the egg. In the continued study of other forms of this insect by experiment and observation, in both field and laboratory, the endeavor has been to secure information upon a number of points. The results may be conveniently arranged under the following heads:

1. Age when wingless form begins to reproduce.
2. Number reproduced in twenty-four hours.
3. Number reproduced in lifetime.
4. Length of life of the wingless individual.
5. Winged migrant—its behavior and life-cycle.
6. Number of moults or ecdyses.
7. Progeny of one individual for one season.
8. Effects on wheat plants as compared with injury wrought by other wheat-infesting species.
9. Time and mode of development of true males and females.
10. Extremes of temperature in which growth, development and reproduction will take place.
11. Food plants.

FIELD AND LABORATORY EXPERIMENTS.

The indoor and outdoor experiments were conducted under lamp-chimneys, the upper end covered with cheese-cloth. Each one of these chimneys covered a potted wheat plant. In the field these pots were sunk in the ground and the whole series shaded somewhat by a cheese-cloth awning. After some time it was found that conditions and results in the laboratory were similar to those in the field, and the field experiments were used only as a check upon the laboratory series, since determination of number of moults was often difficult in the field; a very slight breeze would frequently brush away the exuvia. Field experiments were subject to unavoidable mishaps and vicissitudes, which often made vexatious interruptions in an interesting series. In all cases a single individual green bug was isolated on the potted plant and the offspring removed each day.

During the summer (1907) the temperatures are from Doctor Snow's weather observations. The fall and winter are from self-

recording instruments in both the laboratories and the field. The relative humidity is from the weather station and can be considered only relatively, since obviously this element would vary somewhat with each individual experiment.

In the conduct of this phase of the subject the lines of investigation and methods of procedure used were determined by the writer. The observations and accompanying records were made by Professor Glenn, Mr. Chesky and Miss McDaniels. As will be noted, the results are based on the observations of two and sometimes three investigators working independently on the same problem, the one serving as a check for the other. While the writer worked with these investigators, great credit is due them for the careful attention given to the details of the experiments.

The following pages show a tabulation of experiments on viviparous green bug to determine (1) average length of life in days; (2) average number of offspring; (3) average period of reproduction; (4) average number of moults; (5) average age at which reprodution begins; (6) average daily reproduction per insect during lifetime; (7) average daily reproduction per insect during period of reprodotuion. I=during the summer; II=during the fall, winter and spring.

In the following tables of data, *b* stands for born, the sign (¶) after *b* means born and reared in the laboratory, *m* stands for moulted, *w* for winged, *a* for adult, *d* for died, and *dis.* for disappeared. The numerals stand for the number of young. Numerals before *m* denote the number of individuals moulting on that day, and before *b*, in experiment 6A, the number of young born. The date on which the observation was made stands to the left. The column headed "Relative number produced by ten daily" was obtained by counting the whole number of young produced each day by the adults under observation, and computing how many ten adults would have produced at the same rate. In working out this column in cases where no observations are recorded for certain days, as Sunday, and the record for the following day included the number of young born both days, the results have been divided by two, and one-half the total number assigned to each.

The column headed "Relative number produced by ten weekly," was obtained by taking the total number produced daily by ten for each week.

TABLE I. COMPLETE LIFE-CYCLES. During summer

MONTH.	Max. tem.	Min. tem.	Rel. humidity.	Rain, in.	2C	4C	14C	15A	17A	18A	19A	20A	21A	22C	23A	25A	26A	27A	28A	29C
1907.																				
May 21	86°	55°	63½					b.												
" 22	86	66	62																	
" 23	86.5	64	67½																	
" 24	75	65	85⅞	0.25																
" 25	82	61.5	52½																	
" 26	65	51.5	59½			b.														
" 27	57.5	40	52⅜					1												
" 28	69	45	59					3												
" 29	62	45	79⅜					4												
" 30	58.5	58.5	100	0.80				3												
" 31	62	54	92⅜					3												
June 1	71	49.5	55⅜	0.10				4												
" 2	77	53	60½		b.			4												
" 3	74	59	73					4												
" 4	76	55	56½			1	b.	3	b.	b.	b.	b.	b.		b.	b.	b.	b.	b.	
" 5	78	53	57			3		6	m.	m.			m.					m.		
" 6	74	55.5	79½	0.70°		2	m.	2		m.	m.	m.					m.	m.	m.	
" 7	85.5	72	79			3	m.	2	m.		m.	m.	m.		m.	m.	m.		m.	
" 8	76.5	59.5	89⅜			4	m.	3			m.				m.					
" 9	74	60.5	92½	1.18°		2		1												
" 10	80	57	62½		2	3	m.	0	m.	m.	m.	m.	m.		m.	m.	m.	m.	m.	
" 11	85	55	61½		4	2	4	0	m.			3m.	4	b.			2m.		3m.	
" 12	86.5	65.5	74½	0.08°	5	5	2	0	3m.	3m.	3m.	4	4		4m.	2m.	2	2m.	3	
" 13	88	69.5	78.5		6	0	5	4	3	3	2	5	5	m.	2	2	2	2	3	
" 14	85	68	75⅜		3	4	4	3	2	3	3	4	3	m.	4	2	2	3	3	
" 15	89	67	73⅜		5	5	2	1	3	2	1	4	4	m.	5	2	2	4	1	
" 16	89	69	71⅛		4	4	3	2	1	1	3	4	4	3m.	3	3	2	2	4	
" 17	86	66	64½		3	4	3	2	0	1	2	4	4	3	3	2	2	1	3	
" 18	86	65	76⅜		2	3	3	2	2	3	3	4	2	6	3	2	2	1	3	d.
" 19	78	68	82	0.68	1	2	3	1	2	2	4	3	3	5	2	2	2	2	2	m.
" 20	82	62	75⅜		2	1	4	1	1	1	4	3	3	7	2	2	2	2	2	
" 21	77.5	65	82	0.41	2	0	4	2	1	1	4	3	3	7	2	2	2	2	2	m.
" 22	81	64.5	85⅞	1.79	3	4	2	1	1	1	6	4	2	6	2	2	2	2	2	4m.
" 23	85	63.5	81		3	3	3	2	1	1	2	2	3	3	3	2	2	3	3	5
" 24	88	70.5	78	0.92	4	2	4	2	1	1	2	2	4	3	4	2	2	3	3	6
" 25	78	64	79.7		2	1	3	1	1	1	2	2	1	1	1	1	2	3	2	5
" 26	78.5	60.5	70⅜		1	1	2	1	1	1	3	1	1	2	0	2	2	3	3	4
" 27	77	58	74		2	1	2	2	1	3	2	1	2	4	1	2	2	2	3	4
" 28	81	60.5	72⅜		2	2	2	2	1	1	2	0	1	3	2	1	2	1	2	5
" 29	87.5	64	38⅜	1.66°	3	2	2	2	1	0	3	0	2	4	1	2	1	2	3	4
" 30	86	66	81		1	0	1	1	1	2	1	0	1	4	0	2	1	2	1	4
July 1	86	65	73		1	1	1	1	0	1	0	0	0	4	0	2	0	1	0	4
" 2	84	65.5	75½		2	0	1	0	0	1	0	0	0	2	0	2	0	2	2	4

July 3	86	65	71½	.....	3	0	0	2	0	0	0	0	0	3	1	1	0	1	1	3
" 4	89.5	68	70	.....	2	0	0	1	0	0	0	0	d.	3	0	1	0	1	1	4
" 5	89.5	69	66	.....	1	0	0	0	0	0	0	0	.....	2	0	0	0	0	0	3
" 6	90	69	66½	†	3	0	0	0	0	0	0	d.	.....	1	0	0	0	0	0	3
" 7	89	67	69¾	.....	1	0	0	0	0	0	0	.....	.....	3	0	0	0	d.	0	2
" 8	94	72	68	.....	1	d.	d.	0	d.	d.	.....	.....	d.	3	0	d.	d.	.....	0	2
" 9	88.5	72.5	74	.....	1	.....	.....	d.	.....	.....	.....	.....	.....	2	0	.....	.....	.....	0	0
" 10	85	69	87½	0.16	0	.....	.....	.....	.....	.....	.....	.....	.....	1	0	.....	.....	.....	0	0
" 11	76.5	69.5	74	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	1	0	.....	.....	.....	0	0
" 12	82.5	68.5	70.8	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	1	d.	.....	.....	.....	0	0
" 13	86	64	69.1	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	.....	.....	0	0
" 14	88	60.5	83½	0.34	1	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	.....	.....	0	0
" 15	88	70	87½	†	1	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	.....	.....	0	0
" 16	87.5	77	78	†	0	.....	.....	.....	.....	.....	.....	.....	.....	d.	.....	.....	.....	.....	0	0
" 17	88	71	83½	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	d.	0
" 18	87.5	72	78.5	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
" 19	93	75	68	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0
" 20	91	73	72	.....	d.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	p
" 21	92	73	60½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 22	87	75	83½	0.48*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 23	96	75	77½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 24	97	74	56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 25	98	75	61¾	0.25*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 26	77	69	79	0.47*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 27	75	64	94½	1.21*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 28	76	67	90½	0.46*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 29	81	65	69¾	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 30	85	65	72	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 31	82	67	73¾	0.07*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Length of life					48	43	34	49	34	34	32	30	34	35	38	34	34	33	43	33
Total number of offspring					95	63	60	79	27	33	53	53	55	88	45	41	58	45	56	66
Period of reproduction					40	26	22	39	19	21	19	17	20	27	22	23	20	23	24	17
Number of moults					‡	‡	4	‡	5	4	5	4	3	4	4	4	4	5	4	4
Age when reproduction began, days					8	9	7	6	8	8	8	7	7	5	8	8	7	8	7	5

* Thunder.
† Sprinkle.
‡ No notes taken.

b Born.
m Moulted.
m With numeral, = number born.
d Died.

TABLE I—CONCLUDED. COMPLETE LIFE-CYCLES. During summer.

MONTH.	Max. tem.	Min. tem.	Rel. humidity.	Rain, in.	30B	31A	32A	33A	34A	35A	36A	37A	38A	39A	42A	44A	47A	48B	54B
1907.																			
May 21	85°	55°	63½																
" 22	86	66	62																
" 23	86.5	64	67½																
" 24	75	66	85½	0.25															
" 25	82	61.5	52½																
" 26	65	51.5	59½																
" 27	57.5	40	52⅞																
" 28	69	45	59																
" 29	62	45	79⅜																
" 30	58.5	53.5	100	0.80															
" 31	62	54	92⅔																
June 1	71	49.5	55½	0.10															
" 2	77	53	60½																
" 3	74	59	73																
" 4	76	55	56½			b.	b.	b.	b.	b.	b.	b.	b.						
" 5	73	53	57			m.					m.			b.	b.	b.	b.		
" 6	74	55.5	79½	0.70			m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.		
" 7	85.5	72	79			m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.		
" 8	76.5	59.5	89⅜														m.		
" 9	74	60.5	92½	1.13°			m.					m.							
" 10	80	57	62½			m.		m.	m.	m.	m.		m.	m.	m.	m.	m.		
" 11	85	55	61½					m. 4		m. 3	m. 3	m. 2	m. 2		m. 1				
" 12	86.5	65.5	74½	0.03°		m. 1	m. 1	5	m. 2	3	3	2	3	m. 4	4	m. 4	3		
" 13	88	69.5	78.5		b.	2	3	3	1	3	5	2	4	4	5	5	3		
" 14	85	68	75½		m.	2	3	7	2	3	3	3	2	3	4	6	3		b.
" 15	89	67	73½		m.	3	3	4	2	2	4	2	3	3	4	5	4		m.
" 16	89	69	71½			2	3	4	0	2	3	2	2	3	4	5	5		
" 17	86	66	64½		m.	2	3	4	2	2	2	1	1	2	3	5	5	b.	m.
" 18	86	65	76¾		m.	2	4	4	1	2	3	1	1	3	2	5	5		
" 19	78	68	82	0.68	4	1	3	5	1	1	2	1	1	3	1	4	5	m.	
" 20	82	62	75⅝		2	2	2	3	0	3	1	2	1	3	2	3	3		m.
" 21	77.5	65	82	0.41	2	2	2	3	0	2	1	1	2	3	3	3	3	m.	m.
" 22	81	64.5	85⅝	1.79	2	2	3	1	4	3	0	2	1	3	3	3	3	m.	2
" 23	85	63.5	81		2	1	6	1	3	2	1	1	1	5	2	3	5	m.	2
" 24	88	70.5	78	0.92	2	1	7	1	3	2	2	1	0	5	2	4	5	3	2
" 25	78	64	79.7		3	1	5	2	2	3	2	2	1	2	2	2	4	3	2
" 26	78.5	60.5	70⅔		2	1	6	1	2	3	2	2	1	1	2	2	4	2	2
" 27	77	58	74		1	2	3	1	1	3	1	2	1	1	2	2	3	2	2
" 28	81	60.5	72⅔		1	3	3	1	2	3	0	1	1	2	1	2	3	2	1
" 29	87.5	64	83¾	1.66°	2	3	4	2	3	2	0	0	0	1	2	1	3	1	2
" 30	86	65	81		2	2	5	1	4	0	1	0	1	1	2	2	3	1	2
July 1	86	65	73		3	2	5	2	3	0	1	0	1	1	2	0	3	2	3
" 2	84	65.5	75½		5	2	2	0	3	0	0	0	1	1	0	0	0	2	3

July 3	86	65	71½	.....	4	3	2	2	2	2	0	0	1	0	0	0	0	2	2
" 4	89.5	68	70	.....	3	2	1	1	1	1	0	0	0	0	0	0	0	2	2
" 5	89.5	69	66	.....	3	3	2	2	0	0	0	0	0	0	0	0	0	3	3
" 6	90	69	66½	‡	2	2	2	0	0	0	0	0	d.	d.	0	0	0	3	2
" 7	89	67	69¾	.....	3	1	0	0	d.	d.	0	0	.....	.....	0	0	0	3	2
" 8	94	72	68	.....	4	0	0	0	.....	.....	0	0	.....	.....	0	0	0	3	1
" 9	88.5	72.5	74	.....	3	0	0	d.	.....	.....	d.	0	.....	.....	0	0	0	2	0
" 10	85	69	87½	0.16	3	0	0	.....	.....	.....	.....	0	.....	.....	0	0	0	4	0
" 11	76.5	69.5	74	.....	2	d.	0	.....	.....	.....	.....	0	.....	.....	0	0	0	3	0
" 12	82.5	63.5	70.8	.....	3	.....	0	.....	.....	.....	.....	0	.....	.....	0	0	d.	4	0
" 13	86	64	69.1	.....	2	.....	d.	.....	.....	.....	.....	0	.....	.....	0	0	.....	3	0
" 14	88	60.5	83½	0.34	1	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	2	0
" 15	88	70	87½	†	0	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	1	0
" 16	87.5	77	78	†	d.	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	0	0
" 17	88	71	83½	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	d.	d.
" 18	87 5	72	78.5	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 19	93	75	68	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 20	91	73	72	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 21	92	73	60½	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 22	87	75	83⅜	0.48*	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 23	96	75	77½	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 24	97	74	56	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 25	98	75	61⅜	0.25*	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 26	77	69	79	0.47*	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 27	75	64	94½	1.21*	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 28	76	67	90½	0.46*	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 29	81	65	69¾	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 30	85	65	72	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
" 31	82	67	73¾	0.07*	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	0	0	.....	.....	.....
Length of life, days					33	37	39	35	33	33	35	32	32	32	32	31	37	30	33
Total number of offspring					66	49	79	70	44	49	40	30	34	54	52	66	78	54	36
Period of reproduction					26	26	23	25	22	24	21	18	23	21	21	18	18	23	17
Number of moults					4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Age when reproduction began, days					6	8	8	7	8	7	7	7	7	7	6	7	7	6	8

* Thunder. † Sprinkle. ‡ No notes taken.

Average length of life in days	35.22+	Average period of reproduction, days	22.74+
Average number of offspring	55.42	Average age at which reproduction begins, days	7.16
Average daily reproduction per bug during lifetime	1.57	Usual number of moults	4
Average daily reproduction per bug during period of reproduction	2.43		

TABLE II. LIFE-CYCLES NOT COMPLETE. Summary of data upon fifty-four green bugs selected at various ages. 1907.

NUMBER.	Moults.	Number of offspring.	Number of days observed.	Period of reproduction, days.	Age at first reproduction, days.	NUMBER.	Moults.	Number of offspring.	Number of days observed.	Period of reproduction, days.	Age at first reproduction, days.
1A	†	79	44	25	†	18B	4	6	14	5	6
2B	†	28	12	12	†	19B	4	28	17	9	7
3B	†	29	13	13	†	20B	4	7	13	5	6
3C	†	41	29	18	†	21B	4	5	10	3	7
4D	4	6	8	2	6	24A	5	32	22	14	8
5A	†	49	39	32	†	24B	3	48	23	16	5
5B	4	2	15	7	†	25B	4	18	16	8	6
6B	†	26	35	28	†	26B	3	53	24	15	6
6C	4	2	15	8	7	27B*	4	4	9	2	7
7D	3	31	29	20	8	27C	4	15	16	6	9
8A	†	28	20	20	†	34B	4	3	9	2	7
8B*	5	18	18	11	6	35B*	5	15	14	7	6
8C	4	12	11	4	7	37B*	4	3	9	1	8
9A	†	90	45	43	†	38B*	4	10	17	6	7
9B	4	18	17	10	6	39B	4	13	12	6	6
10C	†	56	32	2.	†	40A*	4	35	25	16	9
13D	4	21	16	10	6	41A*	4	58	25	17	8
11C	†	73	27	23		42B	4	31	23	16	5
11D	3	11	12	6		43A	4	40	22	15	7
12A	†	82	40	38	†	45A	4	40	22	14	8
12B	4	22	18	12	6	45B	4	3	7	1	6
13C	†	30	29	19	†	49B	4	42	18	12	6
13D	4	19	14	8	6	50C	†	22	24	16	7
14D	4	11	19	11	6	52C	4	10	31	10	6
15B	4	3	10	2	7	55B*	5	11	11	3	8
16A	†	35	21	14	7						
16B	4	40	22	15	7	Total...	160	1,363	1,077	683	269
16C	4	15	14	8	6	Average,	4	23½	19½	12½	6.7
17B	4	39	20	13	7						

* Became winged at last molt. † No note taken.
Average daily reproduction, 1.26.
Average daily reproduction during the reproductive period, 2.

TABLE III. 1907. Summary on the winged viviparous female.

SERIAL NUMBER.	Moult.	Number of offspring.	Days observed.	Period of reproduction, days.	Age, first offspring, days.
8B	5	18	18	11	6
27B	4	4	9	2	7
35B	5	15	14	7	6
37B	4	3	9	1	8
38B	4	10	17	6	7
40A	4	35	25	16	9
41A	4	58	25	17	8
55B	5	11	11	3	8
54B	4	36	33	17	8
Averages	4	21.1	17.7	9	7.4

Average number produced daily during reproduction period, 2.4.
Average number produced daily during whole period of observation, 1.1.

FIG. 23. Parasitized "green bugs" on wheat-blades. From photograph, enlarged. (Original.)

TABLE IV. FIELD EXPERIMENTS ON DEVELOPMENT AND REPRODUCTION.

DATE.	Temperature.			Number of experiment.																											Mean weekly temperature.	Relative number produced by ten weekly.	Relative number produced by ten daily.
	Max.	Min.	Mean.	Rain.	Rel. humidity.	1A.	2A.	3A.	4A.	5A.	6A.	7A.	8B.	9B.	10B.	11B.	12B.	13B.	14B.	15A.	16A.	17A.	18A.	19A.	20A.	21A.	22A.	23A.			
1907.																																	
Dec. 17	32	25	30.68	.....	92	....	....	....	....	....	4b.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 18	24	9	14.83	.....	87	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 19	35	5	16.45	.....	66	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 20	51	21	30.12	.....	74	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 21	36	17	25.83	0.22	83	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 22	32	30	31.04	.....	93	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 23	37	24	33.33	.....	73	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 24	51	23	33.91	.....	62	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 25	49	27	34.54	.....	63	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 26	57	26	37.20	.....	73	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 27	61	31	44.26	.....	72	....	....	....	....	....	1m.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 28	64	21	30.81	.....	67	....	....	....	....	....	....	....	b.¶	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 29	54	31	38.25	.....	72	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 30	45	20	41.75	0.02	62	....	....	....	....	....	3m.	....	....	b.¶	b.¶	....	b.¶	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 31	52	20	65.50	.....	63	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1908.																																	
Jan. 1	56	23	34.29	.....	74	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 2	55	21	32.50	.....	68	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 3	40	27	35.33	0.05	85	....	....	....	....	....	....	....	....	....	....	b.¶	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 4	53	28	38.26	.....	74	a.	a.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 5	58	20	31.45	.....	75	0	0	m.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 6	54	24	37.16	.....	63	0	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 7	54	22	36.83	.....	47	0	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 8	51	24	36.20	.....	56	0	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 9	59	24	37.93	.....	60	1	1	0	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 10	75	27	41.16	.....	71	1	0	0	....	....	....	....	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 11	36	23	27.83	.....	67	0	2	0	....	....	....	....	0	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	38	31
" 12	47	20	30.91	.....	65	0	0	0	....	....	....	....	0	....	....	....	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 13	78	21	32.00	.....	58	0	1	0	....	....	....	....	1	....	....	....	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 14	74	16	38.54	.....	62	0	0	0	....	....	....	....	0	1	1	....	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 15	37	11	28.36	.....	67	0	0	0	....	....	....	....	1	0	0	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 16	39	7	18.41	.....	46	0	0	0	....	....	....	....	0	1	0	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" 17	53	17	30.04	.....	48	0	0	0	....	....	....	....	0	0	0	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....

Jan. 18	59	16	31.67		58	0	1	0					0	0	0	0	0												1	15	29
" 19	58	19	35.62		55	0	0	0					1	0	1	0	0												5		
" 20	65	34	41.41		56	0	3	0	w. a.		1m.		0	1	1	0	1												4		
" 21	67	31	47.83		46	0	2	0	0				1	0	0	1	0												5		
" 22	44	23	32.54		58	0	0	0	0				0	0	0	0	0												0		
" 23	37	8	14.29		55	0	0	0	0				0	1	0	0	0												1		
" 24	43	7	21.12		51	d.	0	0	0				1	0	0	1	0												8		
" 25	60	19	34.50		62		0	0	0		1m.		1	1	0	0	1												4	22	35
" 26	69	21	38.54		46		0		0				0	0	1	0	0												5		
" 27	53	14	31.83		47		2	1	1		2m.		2	0	0	0	1												5		
" 28	45	17	30.79		41		1	3	0				2	1	0	0	0												2		
" 29	36	4	17.95		40		1	0	0				0	0	0	0	0												1		
" 30	33	14	28.33		50			0	0			b.¶	2	0	0	1	0												5		
" 31	31	7	29.70		71			0	0				2	1	1	0	0												7		
Feb. 1	23	—1	8.00		67			0	0				d.	0	0	0	0												0	34	29
" 2	44	0	14.83		68			0	0					0	0	0	0												0		
" 3	48	18	29.62		45			dis.	0					0	0	1	0												2		
" 4	42	27	38.26	0.21	98				0					1	1	0	0												4		
" 5	52	26	49.16		62		1		0					0	0	0	1												4		
" 6	51	17	30.20		72		dis.		d.	a.				0	0	0	d.												0		
" 7	67	24	41.75		55						2*			0	0	0													0		
" 8	54	31	43.25		66									0	0	0													0	10	30
" 9	65	33	44.83		68					2				0	0	0													5		
" 10	49	33	47.50		81						1m.			0	0	0													2		
" 11	45	42	42.36	0.31	86							2		0	0	0													2		
" 12	56	38	46.29		73					2		1		1	0	0													8		
" 13	53	37	39.70		81					1		4		0	0	1													12		
" 14	34	24	31.75		80							0		0	1	0		b.¶											2		
" 15	48	20	31.16		75					1		2		0	0	0													6	37	42
" 16	46	27	34.54		74							0		0	0	0													0		
" 17	45	22	32.75	0.38	60					2		1		0	0	0													6		
" 18	41	19	30.04		83					0	dis.	0		0	0	0													0		
" 19	26	11	17.25		85					0		0		0	0	0													0		
" 20	41	10	24.70		84					0		dis.		0	0	0													0		
" 21	47	23	33.33		63					d.				0	0	0													0		
" 22	63	28	42.17		61									0	0	0													0	6	29
" 23	64	31	45.82		59									0	0	dis.													10		
" 24	48	37	42.45	0.39	89									2	2														10		
" 25	55	34	42.20		66									0	8					b.¶	b.¶	b.¶							15		
" 26	43	28	33.95		64									0	0														0		
" 27	43	17	26.83		60									2	6														40		
" 28	70	33	44.70		73									0	0														0		
" 29	47	33	39.62		86									0	8														15	90	40
Mar. 1	42	35	38.58		85									0	0				b.¶										0		
" 2	52	29	38.50		69									0	0														0		
" 3	43	36	39.41	0.02	89									0	3			8											37		
" 4	48	39	42.04	0.26	98									0	0			0											0		
" 5	68	46	57.62	0.08	79									1	3			4		w.	w.								24		
" 6	68	31	48.16		68									d.	d.			2		a.	a.							a.	20		
" 7	60	26	38.33		73													0										0	0	81	38

TABLE IV.—CONCLUDED. FIELD EXPERIMENTS ON DEVELOPMENT AND REPRODUCTION IN FIELD.

Date.	Temperature.			Rain	Rel. humidity	Number of experiment.																							Relative number produced by ten daily	Relative number produced by ten weekly	Mean weekly temperature
	Max.	Min.	Mean.			1A	2A	3A	4A	5A	6A	7A	8B	9B	10B	11B	12B	13B	14B	15A	16A	17A	18A	19A	20A	21A	22A	23A			
Mar. 8	43	28	37.62		67													0										0	6		
" 9	65	31	39.91		55													3	1		1							0	6		
" 10	71	27	48.04		50													1	1		2	1	b.					0	10		
" 11	75	43	55.00		61													1	1		1	0						0	6		
" 12	85	41	59.95		60													1	1	4	1	1						2	17		
" 13	73	42	54.37		61													1	0	0	1	0						8	8		
" 14	85	48	63.50		54													4	2	1	2	8							20	73	50
" 15	81	41	59.58		55													8	1									8	10		
" 16	85	42	64.16		64													2	4	1	3			a.3				2	11		
" 17	76	45	57.95		57													4	1	1	1	4		3				0	20		
" 18	75	35	57.15		61													0	0	1	1	4						2	11		
" 19	56	31	41.25		51													0	0	1	8	0		2				4	14		
" 20	67	33	48.26		40													0	1	0	0	0						0	2		
" 21	68	38	51.66		46													0	0	0	0	0						0	0	68	56
" 22	59	43	50.16		49													0	0									6	11		
" 23	76	33	53.00		48													2	1	0	3	8						0	18		
" 24	80	45	58.41		51													0	1	1	2	1						4	18		
" 25	89	39	69.25		59													5	2	1	1	1		1				1	17		
" 26	74	43	61.25		60													5	2	2	5	5		7				dis.	40		
" 27	85	48	63.83		66													5	0	0	1	8		8					30		
" 28	59	35	45.37		60													8	8	1	0	0	1	4					20	184	58
" 29	66	28	46.70		53													2	1										12		
" 30	55	41	47.20		91													2	1	2	4	1	1	3					12		
" 31	80	50	63.66		71													0	2	8	5	8	4	2	b.	b.	b.		27		
Apr. 1	66	40	50 20		52													2	2	1	2	2	0	2					16		
" 2	55	26	38.70		42													0	0	0	0	0	0	1					1		
" 3	74	30	50.33		35													0	1	0	1	0	0	1					4		
" 4	65	41	49.65	0.26	67													0	2	0	0	0	2	8					10	82	49
" 5	74	39	57.58		70													0	0										9		
" 6	87	49	60.04		73													0	2	2	8	2	2	2					10		
" 7	75	58	64.34	1.05	68													dis.	0	1	4	8	8	2					80		
" 8	61	41	47.79		77														0	0	2	2	2	8					15		
" 9	61	38	48.88		85														1	0	0	0	0	2	m.	m.	m.		5		
" 10	72	51	58.88		82														0	2	2	2	2	0					13		

Apr.	11	71	42	54.91	.....	46	....	....	....	....	....	....	....	....	....	....	....	....	....	2	2	2	7	2	2	....	....	....	....	28	120	56
"	12	76	40	57.41	.....	61	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	8	....	....
"	13	83	50	69.83	.....	70	....	....	....	....	....	....	....	....	....	....	....	....	....	3	1	1	1	2	1	m.	m.	m.	....	9	....	....
"	14	73	60	64.12	0.06	85	....	....	....	....	....	....	....	....	....	....	....	....	....	2	3	5	6	4	2	m.	....	....	....	37	....	....
"	15	89	54	66.08	.....	68	....	....	....	....	....	....	....	....	....	....	....	....	....	2	1	0	2	0	1	....	m.	m.	....	10	....	....
"	16	65	47	53.54	.....	68	....	....	....	....	....	....	....	....	....	....	....	....	....	1	0	3	2	2	1	....	....	....	....	15	....	....
"	17	67	51	58.20	0.98	94	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	1	0	1	0	m.	m.	m.	....	7	....	....
"	18	78	48	62.36	.....	74	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	1	6	2	1	5	4	5	....	29	115	61
"	19	88	53	59.16	.....	65	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....	....	....	....	20	....	....
"	20	88	56	72.00	.....	53	....	....	....	....	....	....	....	....	....	....	....	....	....	4	5	0	1	4	3	3	7	8	....	21	....	....
"	21	87	61	70.54	0.02	67	....	....	....	....	....	....	....	....	....	....	....	....	....	1	3	0	5	3	1	6	3	6	....	31	....	....
"	22	82	59	69.70	0.47	86	....	....	....	....	....	....	....	....	....	....	....	....	....	1	1	0	0	1	1	3	3	5	....	17	....	....
"	23	83	67	73.62	.....	78	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	1	2	1	2	1	1	1	....	10	....	....
"	24	69	60	65.00	0.01	71	....	....	....	....	....	....	....	....	....	....	....	....	....	2	1	d.	3	0	1	2	5	7	....	26	....	....
"	25	86	59	68.16	.....	57	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	....	0	1	0	3	1	1	....	8	153	69
"	26	65	43	56.95	.....	53	....	....	....	....	....	....	....	....	....	....	....	....	....	1	0	....	....	....	....	....	....	....	....	9	....	....
"	27	60	37	48.50	.....	52	....	....	....	....	....	....	....	....	....	....	....	....	....	2	0	....	d.	0	1	1	2	6	....	10	....	....
"	28	65	35	49.37	.....	59	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	....	....	0	0	0	1	0	....	2	....	....
"	29	64	37	48.20	.....	55	....	....	....	....	....	....	....	....	....	....	....	....	....	0	1	....	....	0	0	0	0	1	....	3	....	....
"	30	73	51	51.66	.....	51	....	*.	....	....	....	....	....	....	....	....	....	....	....	dis.	0	....	....	0	0	1	1	1	....	6	....	....
May	1	81	44	60.79	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	0	0	0	1	2	....	3	....	....
"	2	71	37	54.59	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	0	0	1	2	2	....	11	49	54
"	3	61	49	53.29	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	0	0	....	....	....	....	0	....	....
"	4	68	51	58.41	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	0	0	....	....	....	....	0	....	....
"	5	63	52	55.66	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	1	0	1	4	6	....	20	....	....
"	6	51	46	48.41	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	0	....	....	....	....	0	....	....
"	7	65	46	51.95	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	1	0	1	1	2	....	8	....	....
"	8	70	40	55.12	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	d.	0	1	1	4	....	30	....	....
"	9	76	45	64.04	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	0	0	0	1	....	4	62	54
"	10	82	56	69.62	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	0	....	....	....	....	16	....	....
"	11	79	59	66.91	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	d.	0	1	9	....	17	....	....
"	12	78	58	69.12	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	1	3	2	....	20	....	....
"	13	78	63	67.95	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	0	6	6	....	60	....	....
"	14	81	62	69.83	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	0	0	3	....	15	....	....
"	15	88	56	72.36	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	0	5	2	....	35	....	....
"	16	91	63	76.62	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	0	1	1	....	10	173	68
"	17	88	63	71.29	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	0	2	....	....	10	....	....
"	18	....	....	.....	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	d.	0	3	....	15	....	....
"	19	....	....	.....	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	d.	....	....	....	....	....	0	dis.	....	0	....	....
"	20	....	....	.....	.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	d.	....	....	....	....	....
Length of life													84	69	69	51	38	53	60	84	59	61	59	74	48	50	....	....	....	....	....
Total number of offspring						2	19	4	1	8	....	10	15	14	26	7	7	59	60	45	66	81	42	53	30	55	84	30	....	....	....
Period of reproduction													23	52	52	30	26	30	50	49	46	45	41	42	24	29	31	14	....	....	....
Number of moults						‡	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	4	4	....	....	....	....
Age when reproduction begins													11	15	15	13	12	18	8	....	18	14	18	....	18	18	18	....	....	....	....

* Lost. ‡ No notes taken of experiments No. 1 to No. 19, inclusive.
† Reared in the laboratory.

CONCLUSIONS FROM FIELD EXPERIMENTS ON REPRODUCTION.

I. The period of development is greatly influenced by temperature. In December many young were isolated for the purpose of ascertaining the length of this period in the winter months, but not one of them was reared to maturity. They either died, escaped, or were lost before maturing. But that the period of development is greatly prolonged by cold weather may be seen from experiment 6A. In this experiment four young born on December 17 were observed. One cast the first moult December 27, and the other three Decmeber 30. One cast its second moult January 20, another on January 25, and the other two January 27. February 7 two were lost while transferring them to a new plant. On February 10 one of the two remaining cast its third moult. On February 18 a storm blew the tent away and the bugs were lost. So in the case of these four we have:

Number of days from birth to first moult, minimum 10, maximum 13.

Number of days from birth till second moult, minimum 34, maximum 41.

Number of days from birth till third moult, minimum 55, maximum not ascertained.

From these facts we may safely estimate that the period of development of these individuals would have been from seventy-five to ninety days had observations continued till they had cast their fourth moult. In other words, young born the middle of December last (1907) in northeastern Kansas would have matured from the first to the middle of March.

The first one reared in the field was born March 10 (see experiment 18A) and matured March 28, or in 18 days. Three others, born March 31, matured April 17, or in 17 days.

The mean temperature from December 17, 1907, to March 1, 1908, was 35° F. The mean from March 10 to April 28 was 56° F., and the mean from March 31 to April 17 was 58° F.

II. The length of life, period of reproduction, total number of young and average number of young produced daily by each individual for January and February, and also for March, April and May, are shown in the following summaries:

TABLE V. SUMMARY FOR JANUARY AND FEBRUARY, 1908.

	Number of experiment.					Totals.	Average.
	8B	9B	10B	11B	12B		
Length of life	34	69	69	51	38	261	52.2
Reproduction period	23	52	52	30	26	183	36.6
Total number of young	15	14	26	7	7	69	13.8

Average daily number of young for each individual during the reproductive period, 0.374.
Mean temperature for the period, 35° F.

TABLE IV. SUMMARY FOR MARCH, APRIL AND MAY, 1908.

	Number of experiment.										Totals.	Average.
	13B	14B	15A	16A	17A	18A	19A	20A	21A	22A		
Length of life	53	60	84	59	61	59	74	48	50	dis.	548	60.9
Reproduction period	30	50	49	46	45	41	42	24	29	31	387	38.7
Total number of young	59	60	45	66	81	42	53	30	55	84	575	57.5

Average daily number of young for each individual during the reproductive period, 1.5.
Mean temperature for period, 58° F.

The individuals in experiments from No. 13B to 20A were reared in the laboratory, hence the period of development was much shorter than it would have been had they been reared in the field, and the length of life shown in the summary is less than it would be under natural conditions.

INDOOR EXPERIMENTS ON REPRODUCTION DURING WINTER AND SPRING.

These experiments were carried on in the upper laboratory of the department, for the purpose of determining the length of life, number of moults, age when reproduction begins, period of reproduction, average number of young produced by each individual in its lifetime, and the average number produced daily during the period of reproduction. A few experiments with *Macrosiphum granaria* are included for the purpose of comparison. Table No. VII will show a tabulated statement of the data. The abbreviations are the same as in the preceding chart. The column marked "Relative number produced daily by ten individuals" was calculated by ascertaining the whole number produced daily and dividing the sum by the number of insects participating. This gives the average for one insect for one day. This number multiplied by ten gives the factor upon which the variation is based.

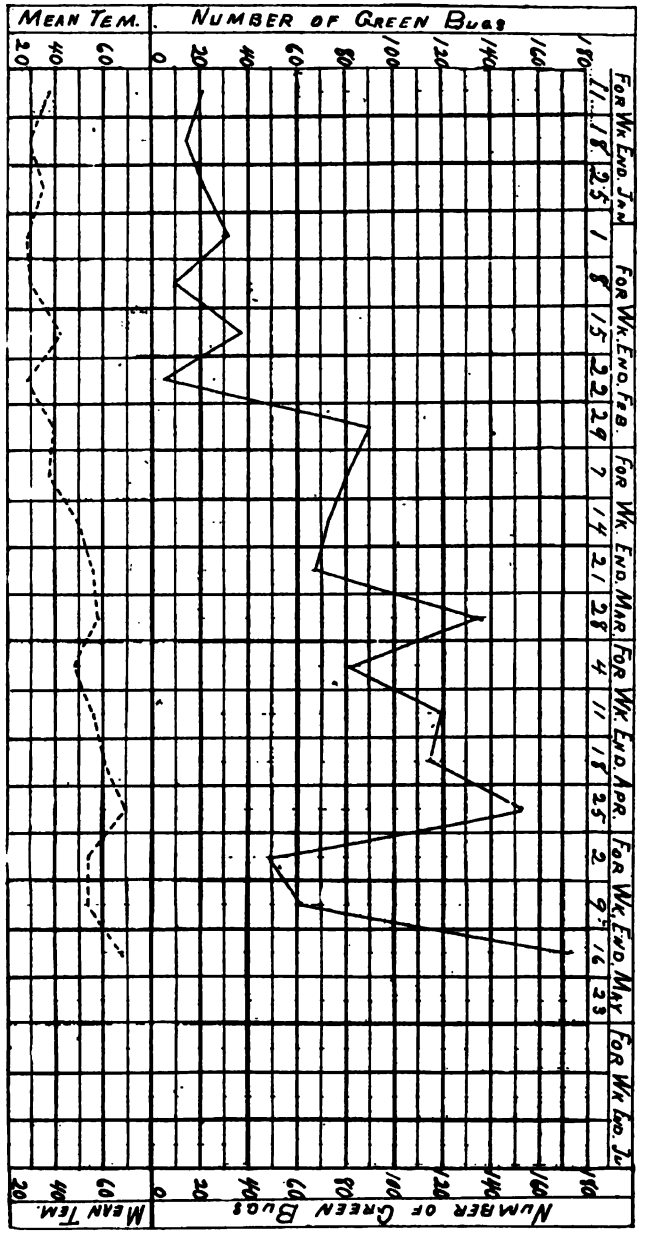


PLATE VI. Chart showing relation between temperature and rate of reproduction, based on number of offspring of ten green bugs during the given period.

TABLE VII.—CONTINUED. INDOOR EXPERIMENTS ON DEVELOPMENT AND REPRODUCTION.

DATE.	Temperature.			*Toxoptera graminum.*																											
	Max.	Min.	Mean.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11B.	12B.	13B.	14B.	15B.	16B.	17B.	18B.	19B.	20B.	21B.	22B.	23B.	E.				
1908.																															
Mar. 7	63	55	58.26										4		3		1	1	1	4	2	2	0	2	3						
" 8	58	48	63.91										0		0		1	1	0	0	0	5	0	0	0						
" 9	79	43	59.43										2		0		0	0	3	3	1	2	0	0	2						
" 10	75	51	62.66										2		3		2	0	3	3	2	2	2	3	1						
" 11	80	54	64.54										3		0		0	0	3	0	2	2	1	3	4						
" 12	76	51	64.54										d.		3		2	0	0	4	1	1	0	1	1						
" 13	84	60	70.04												dis.		dis.	0	1	0	0	0	0	0	4						
" 14	73	56	64.54															0	0	1	0	0	0	0	0						
" 15	73	61	67.16															1	1	1	1	0	0	0	0						
" 16	76	60	69.45															0	0	0	0	0	0	0	0						
" 17	74	63	68.12															0	0	0	0	0	0	0	0						
" 18	72	60	65.33															1	1	1	1	0	0	0	0						
" 19	68	56	61.83															0	0	0	0	0	0	0	0						
" 20	68	54	62.58															1	1	0	0	0	0	0	0						
" 21	62	46	55.08															0	0	0	0	0	0	0	0						
" 22	58	53	65.54															0	0	0	0	0	0	0	0						
" 23	71	49	59.08															0	0	0	0	0	0	0	0						
" 24	70	57	63.79															0	0	0	0	0	0	0	0						
" 25	72	60	65.33															0	0	0	0	0	0	0	0						
" 26	76	65	70.87															0	0	0	0	0	0	0	0						
" 27	77	62	69.58															0	0	0	0	0	0	0	0						
" 28	76	60	67.41															0	0	0	0	0	0	0	0						
" 29	69	58	66.20															0	0	0	0	0	0	0	0						
" 30	67	52	59.25															0	0	0	0	0	0	0	0						
" 31	79	56	66.33															0	0	0	0	0	0	0	0						
Apr. 1	81	63	71.41															0	0	0	0	0	0	0	0						
" 2	80	55	66.58															0	0	0	0	0	0	0	0						
" 3	68	44	56.70															0	0	0	0	0	0	0	0						
" 4	67	47	54.75															0	0	0	0	0	0	0	0						
" 5	67	51	57.79															0	0	0	0	0	0	0	0						
" 6	77	54	66.54															0	0	0	0	0	0	0	0						
" 7	74	65	69.33															0	0	0	0	0	0	0	0						
" 8	78	63	69.41															0	0	0	0	0	0	0	0						

Apr. 9.	68	56	60.83																		0					1
" 10.	66	55	59.83																		0					3
" 11.	69	57	63.50																		0					3
" 12.	69	54	59.41																		0					1
" 13.	74	56	64.70																		0					
" 14.	66	63	64.08																		0					1
" 15.	74	60	71.91																		0					4
" 16.	72	59	64.40																		0					1
" 17.	77	59	63.16																		0					d.
" 18.	74	64	68.33																		d.					
" 19.	81	66	73.37																							
" 20.	81	59	75.95																							
" 21.	80	68	76.45																							
" 22.	75	64	69.70																							
" 23.	77	68	71.75																							
" 24.	69	64	66.83																							
" 25.	74	59	68.58																							
" 26.	69	58	64.54																							
" 27.	64	53	59.95																							
" 28.	64	51	59.95																							
" 29.	67	56	59.66																							
" 30.	70	58	61.25																							
May 1.	80	55	67.70																							
" 2.	73	61	63.17																							
" 3.	65	65	62.25																							
" 4.	76	56	61.16																							
" 5.	64	59	63.17																							
" 6.	66	56	60.16																							
" 7.	69	59	65.83																							
" 8.	69	55	63.04																							
" 9.	73	60	66.83																							
" 10.	76	64	69.70																							
" 11.	78	65	69.04																							
" 12.	70	62	69.70																							
" 13.	74	64	66.75																							
" 14.	76	65	70.33																							
" 15.	81	68	74.25																							
" 16.	84	72	77.20																							
" 17.	79	70	75.00																							
" 18.	78	67	71.91																							
" 19.	82	68	74.95																							
" 20.																										
" 21.																										
" 22.																										
" 23.																										

TABLE VII.—CONTINUED. INDOOR EXPERIMENTS ON DEVELOPMENT AND REPRODUCTION.

DATE.	Temperature.			*Toxoptera graminum.*																							
	Max.	Min.	Mean.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11B.	12B.	13B.	14B.	15B.	16B.	17B.	18B.	19B.	20B.	21B.	22B.	23B.
1908.																											
Mar. 7	63	55	58.26	....	....	....	....	....	....	....	....	....	4	....	3	....	1	1	1	4	2	2	0	3	3	....
" 8	58	48	63.91	....	....	....	....	....	....	....	....	....	0	....	0	....	1	1	0	0	0	5	0	0	0	....
" 9	79	43	59.43	....	....	....	....	....	....	....	....	....	2	....	0	....	0	0	3	3	1	2	2	2	2	....
" 10	75	51	62.66	....	....	....	....	....	....	....	....	....	3	....	0	....	2	1	4	5	2	1	1	3	1	....
" 11	80	54	64.54	....	....	....	....	....	....	....	....	....	d.	....	3	....	0	0	0	1	4	0	0	4	6	....
" 12	76	51	64.54	....	....	....	....	....	....	....	....	....	....	....	dis.	....	2	d.	1	1	0	0	0	0	0	....
" 13	84	60	70.04	....	....	....	....	....	....	....	....	....	....	....	....	....	dis.	....	0	2	1	1	0	0	0	....
" 14	73	56	64.54	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	1	0	0	0	0	....
" 15	73	61	67.16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	0	0	0	0	0	0	....
" 16	76	60	69.45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 17	74	63	68.12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 18	72	60	65.83	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 19	68	56	61.83	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 20	68	54	62.58	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 21	62	46	55.08	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 22	58	53	65.54	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 23	71	49	59.08	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 24	70	57	63.79	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 25	72	60	65.33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 26	76	65	70.87	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 27	77	62	69.58	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 28	76	60	67.41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 29	69	58	66.20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 30	67	52	59.25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 31	79	56	66.33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
Apr. 1	81	63	71.41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 2	80	55	66.58	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 3	68	44	56.70	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 4	67	47	54.75	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 5	67	51	57.79	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 6	77	54	66.54	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 7	74	65	69.33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	0	0	0	0	0	....
" 8	78	63	69.41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	d.	0	0	0	0	....

Apr. 9	68	56	60.83																		0					1
" 10	66	55	59.83																		0					8
" 11	69	57	63.50																		0					3
" 12	69	54	59.41																		0					1
" 13	74	56	64.70																		0					
" 14	66	63	64.08																		0					1
" 15	74	60	71.91																		0					4
" 16	72	59	64.40																		0					1
" 17	77	59	63.16																		0					d.
" 18	74	64	68.33																		d.					
" 19	81	66	73.37																							
" 20	81	59	75.95																							
" 21	80	68	76.45																							
" 22	75	64	69.70																							
" 23	77	68	71.75																							
" 24	69	64	66.83																							
" 25	74	59	68.58																							
" 26	69	58	64.54																							
" 27	64	53	59.95																							
" 28	64	51	59.95																							
" 29	67	56	59.66																							
" 30	70	58	61.25																							
May 1	80	55	67.70																							
" 2	73	61	68.17																							
" 3	65	65	62.25																							
" 4	76	56	61.16																							
" 5	64	59	68.17																							
" 6	66	56	60.16																							
" 7	69	59	65.88																							
" 8	69	55	63.04																							
" 9	73	60	66.88																							
" 10	76	64	69.70																							
" 11	73	65	69.04																							
" 12	70	62	69.70																							
" 13	74	64	66.75																							
" 14	76	65	70.33																							
" 15	81	68	74.25																							
" 16	84	72	77.20																							
" 17	79	70	75.00																							
" 18	78	67	71.91																							
" 19	82	68	74.95																							
" 20																										
" 21																										
" 22																										
" 23																										

TABLE VII.—CONTINUED. INDOOR EXPERIMENTS ON DEVELOPMENT AND REPRODUCTION

DATE.	Temperature.			*Toxoptera graminum.*																	*Macrosiphum granaria.*				
	Max.	Min.	Mean	24B.	25B.	26B.	27B.	28.	29B.	30B.	31B.	32B.	33B.	34B.	35B.	36B.	37B.	Relative number produced daily by ten.	Relative number produced weekly by ten.	Mean weekly temperature.	38.	39.	40B.	41B.	50.
1907.																									
Dec. 16	73	44	55.37																						
" 17	72	51	61.04																						
" 18	69	50	60.66																						
" 19	66	39	59.58																						
" 20	75	40	57.05																						
" 21	71	48	58.20																						
" 22	54	46	47.83																						
" 23	68	43	55.29																						
" 24	82	47	56.95																						
" 25	60	46	51.79																						
" 26	71	43	56.79																						
" 27	78	51	62.50																						
" 28	72	51	66.66																						
" 29	55	48	51.37																						
" 30	77	45	58.66																						
" 31	68	42	55.54																						
1908.																									
Jan. 1	62	49	55.16															30							
" 2	74	44	58.54															20			d.				
" 3	63	49	55.54																						
" 4	69	50	59.58															30							
" 5	60	49	53.50																						
" 6	66	46	55.04																						
" 7	74	46	59.76																						
" 8	78	51	63.91															50							
" 9	68	47	55.00																						
" 10	78	51	63.45																						
" 11	74	52	61.83															43	93	58	w.p.				
" 12	56	47	55.41															16							
" 13	69	44	58.71															17							
" 14	70	45	55.83															27			d.				
" 15	71	43	63.33															30							
" 16	78	42	60.58															33			4				

Jan. 17	71	33	58.87															11							
" 18	78	50	61.70															12	146	59	4				
" 19	57	48	50.00															18							
" 20	70	44	55.63															19			2				
" 21	80	52	66.04															13			3				
" 22	72	56	64.45															10							
" 23	70	51	61.37															27			3				
" 24	55	36	43.66															13			1				
" 25	66	35	49.70															7	107	58	2				
" 26	62	47	51.50															8							
" 27	69	43	56.45															9			3				
" 28	74	49	54.41															10			1				
" 29	71	45	56.70															3			8				
" 30	70	46	59.62															13			0				
" 31	71	52	63.58															7			4				
Feb. 1	74	64	64.41															17	67	56	1				
" 2	64	35	47.54															6							
" 3	69	31	52.16															7			2				
" 4	66	48	56.66															10			3				
" 5	76	55	64.54															15			2				
" 6	81	49	64.75															13			1				
" 7	74	52	62.29															16							
" 8	78	52	63.41															16	83	55					
" 9	66	55	60.83															16							
" 10	72	52	63.10															58			5				
" 11	68	54	61.08															9			2				
" 12	78	51	61.91															25			0				
" 13	80	55	66.45															23			0				
" 14	71	53	61.83															21			0				
" 15	77	51	59.58															15	167	62	2				
" 16	55	46	55.83															10							
" 17	41	69	56.29															10			0				
" 18	69	49	62.62															27			1				
" 19	75	57	67.25															23			d.				
" 20	63	47	55.83															17							
" 21	77	47	61.50															17							
" 22	74	45	59.00															18	122	60					
" 23	64	53	57.91															18							
" 24	64	48	56.54															24							
" 25	72	53	61.54															18							
" 26	74	52	61.54															29							
" 27	77	50	63.33															28							
" 28	78	57	62.70															21							
" 29	72	55	62.70															20	158	61					
Mar. 1	58	47	51.62															5							
" 2	74	44	67.62															28				w.p.			
" 3	75	54	64.45															27							
" 4	75	60	65.25															22							
" 5	69	60	65.33															33							
" 6	79	62	68.45	b.														25				a.			

TABLE VII.—CONCLUDED. INDOOR EXPERIMENTS ON DEVELOPMENT AND REPRODUCTION.

DATE.	Temperature.			*Toxoptera graminum.*																					*Macrosiphum granaria.*				
	Max.	Min.	Mean.	24B.	25B.	26B.	27B.	28.	29B.	30B.	31B.	32B.	33B.	34B.	35B.	36B.	37B.	Relative number produced daily by ten.	Relative number produced weekly by ten.	Mean weekly temperature.	38.	39.	40B.	41B.	42.
1908.																											
Mar. 7	63	55	58.26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	21	156	63	....	....	....	....	....
" 8	58	48	53.91	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6			....	2	....	....	....
" 9	79	48	59.43	m.	....	....	....	....	....	....	....	....	....	....	....	....	....	16			....	0	....	....	....
" 10	75	51	62.66	....	b.	....	....	....	....	....	....	....	....	....	....	....	....	21			....	....	....	....	....
" 11	80	54	64.54	m.	....	....	....	....	....	....	....	....	....	....	....	....	....	11			....	3	....	....	....
" 12	76	51	64.54	m.	m.	....	....	....	....	....	....	....	....	....	....	....	....	18			....	2	....	....	....
" 13	84	60	70.04	....	m.	b.	....	....	....	....	....	....	....	....	....	....	....	18			....	8	....	....	....
" 14	73	56	64.54	m.	....	....	....	....	....	....	....	....	....	....	....	....	....	13	108	62	....	....	....	....	....
" 15	73	61	67.16	....	m.	m.	....	....	....	....	....	....	....	....	....	....	....	9			....	0	....	....	....
" 16	76	60	69.45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	22			....	4	....	....	....
" 17	74	63	68.12	5	m.	m.	....	....	....	....	....	....	....	....	....	....	....	24			....	2	....	....	....
" 18	72	60	65.33	0	1	m.	b.	b.	....	....	....	....	....	....	....	....	....	22			....	1	....	....	....
" 19	68	56	61.33	0	2	....	m.	....	b.	b.	....	....	....	....	....	....	....	14			....	0	....	....	....
" 20	68	54	62.58	4	1	m.	....	m.	m.	....	b.	....	....	....	....	....	....	15			....	0	....	....	....
" 21	62	46	55.08	0	4	....	....	....	m.	....	....	....	....	....	....	....	....	5	111	66	....	....	....	....	....
" 22	58	53	55.54	0	4	....	m.	....	....	....	m.	....	....	....	....	....	....	10			....	1	....	....	....
" 23	71	49	59.08	3	7	m.	m.	....	....	m.	m.	b.	....	....	....	....	....	24			....	1	....	....	....
" 24	70	57	63.79	2	0	....	....	m.	....	....	....	....	....	....	....	....	....	14			....	1	....	....	....
" 25	72	60	65.33	2	9	1	m.	....	m.	m.	m.	m.	b.	....	....	....	....	28			....	0	....	....	....
" 26	76	65	70.87	4	7	5	....	....	m.	m.	m.	....	....	....	....	....	....	28			....	1	....	....	....
" 27	77	62	69.58	4	4	4	....	m.	....	m.	m.	m.	m.	....	....	....	....	26			....	2	....	....	....
" 28	76	60	67.41	0	4	4	....	....	5	m.	m.	m.	....	b.	....	....	....	25	143	64	....	0	....	....	....
" 29	69	58	66.20	0	0	7	7	m.	2	2	5	....	m.	....	b.	....	....	23			....	0	....	....	....
" 30	67	52	59.25	2	4	7	2	1	3	5	5	m.	m.	m.	....	....	....	30			....	0	....	....	....
" 31	79	56	66.33	6	7	1	6	3	2	3	6	....	....	m.	m.	....	....	40			....	0	....	....	....
Apr. 1	81	63	71.41	1	8	0	4	2	0	3	4	3	m.	m.	....	....	....	26			....	1	b.	b.	b.
" 2	80	55	66.58	3	1	1	3	0	2	3	1	1	3	0	....	....	....	26			....	dis.	....	....	....
" 3	68	44	56.70	1	0	2	1	2	2	1	0	2	2	7	....	....	....	19			....	....	m.	....	....
" 4	67	47	54.75	0	2	2	4	2	3	0	2	2	3	7	....	....	....	26	186	65	....	....	m.	m.	m.
" 5	67	51	57.79	2	2	3	4	3	2	2	3	2	3	0	m.	....	....	28			....	....	....	....	....
" 6	77	54	66.54	2	3	3	6	2	2	4	4	2	4	4	m.	....	....	33			....	....	m.	....	m.
" 7	74	65	69.33	1	5	4	5	1	1	1	5	1	3	0	m.	....	....	30			....	....	....	m.	....
" 8	78	63	69.41	3	5	4	1	2	1	1	3	1	0	4	2	b.	....	33			....	....	m.	....	....

Apr. 9....	68	56	60.83	1	1	1	1	2	1	1	5	1	2	0	0	m.	....	14	....	....	....	....	m.	m.	....
" 10....	66	55	59.83	0	0	1	2	1	2	3	4	1	3	1	0	....	....	18	....	....	....	....	6	....	....
" 11....	69	57	63.50	5	0	0	2	....	0	3	3	3	0	0	0	....	....	16	165	62	....	....	0	m.	m.
" 12....	69	54	59.41	0	2	1	2	0	2	6	2	2	6	1	6	m.	....	26	....	....	....	....	0	m.	....
" 13....	74	56	64.70	3	1	2	4	0	3	1	2	5	3	2	1	m.	....	23	....	....	....	....	0	2	2
" 14....	66	68	64.08	0	2	3	1	3	1	4	1	1	1	5	1	....	....	20	....	....	....	....	0	3	2
" 15....	74	60	71.91	4	0	5	2	4	4	4	1	2	3	4	1	m.	....	32	....	....	....	....	9	3	1
" 16....	72	59	64.40	3	0	2	2	1	1	2	0	3	2	1	1	6	b.	19	....	....	....	....	1	3	0
" 17....	77	59	63.16	2	0	1	1	2	1	3	0	1	3	3	2	2	....	26	....	....	....	....	3	3	....
" 18....	74	64	68.33	2	0	2	3	....	1	0	0	0	0	0	0	3	m.	10	156	65	....	....	2	1	4
" 19....	81	66	73.87	0	0	2	2	4	5	3	0	2	3	2	2	3	....	28	....	....	....	....	2	2	2
" 20....	81	59	75.95	1	d.	4	0	2	d.	2	0	3	5	4	2	3	m.	23	....	....	....	....	0	1	2
" 21....	80	68	76.45	3	....	3	2	1	....	1	1	2	1	0	3	2	m.	17	....	....	....	....	2	2	2
" 22....	75	64	69.70	2	....	2	d.	0	....	2	2	0	d.	d.	0	3	m.	16	....	....	....	....	2	0	1
" 23....	77	68	71.75	0	....	2	....	1	....	d.	0	0	....	....	0	1	....	8	....	....	....	....	1	2	0
" 24....	69	64	66.83	1	....	2	....	1	....	....	0	0	....	....	1	0	2	14	....	....	....	....	1	2	....
" 25....	74	59	68.58	0	....	6	....	....	....	....	0	0	....	....	0	0	0	12	118	72	....	....	1	0	3
" 26....	69	58	64.54	0	....	4	....	1	....	....	0	0	....	....	1	2	2	20	....	....	....	....	3	0	0
" 27....	64	53	59.95	d.	....	0	....	0	....	....	0	0	....	....	0	1	1	5	....	....	....	....	2	0	2
" 28....	64	51	59.95	....	....	1	....	....	....	....	0	0	....	....	0	0	0	3	....	....	....	....	0	1	0
" 29....	67	56	59.68	....	....	0	....	....	....	....	0	0	....	....	0	1	1	7	....	....	....	....	0	0	0
" 30....	70	58	61.25	....	....	0	....	....	....	....	0	0	....	....	0	1	0	8	....	....	....	....	3	1	4
May 1....	80	55	67.70	....	....	0	....	....	....	....	0	0	....	....	3	3	2	27	....	....	....	....	2	0	....
" 2....	73	61	68.17	....	....	0	....	....	....	....	0	0	....	....	2	0	3	17	82	63	....	....	0	1	2
" 3....	65	65	62.25	....	....	0	....	....	....	....	0	0	....	....	1	2	0	10	....	....	....	....	0	0	1
" 4....	76	56	61.16	....	....	0	....	....	....	....	0	0	....	....	d.	2	2	20	....	....	....	....	d.	d.	1
" 5....	64	59	68.17	....	....	0	....	d.	....	....	0	0	....	....	....	0	1	5	....	....	....	....	....	....	2
" 6....	66	56	60.16	....	....	0	....	....	....	....	0	d.	....	....	....	0	1	5	....	....	....	....	....	....	2
" 7....	69	59	65.83	....	....	d.	....	....	....	....	0	....	....	....	....	1	0	5	....	....	....	....	....	....	2
" 8....	69	55	63.04	....	....	....	....	....	....	....	0	....	....	....	....	0	0	0	....	....	....	....	....	....	....
" 9....	73	60	66.83	....	....	....	....	....	....	....	0	....	....	....	....	0	1	5	50	68	....	....	....	....	1
" 10....	76	64	69.70	....	....	....	....	....	....	....	0	....	....	....	....	1	1	10	....	....	....	....	....	....	2
" 11....	73	65	69.04	....	....	....	....	....	....	....	0	....	....	....	....	3	1	20	....	....	....	....	....	....	0
" 12....	70	62	69.70	....	....	....	....	....	....	....	0	....	....	....	....	1	1	10	....	....	....	....	....	....	0
" 13....	74	64	66.75	....	....	....	....	....	....	....	0	....	....	....	....	1	2	15	....	....	....	....	....	....	0
" 14....	76	65	70.33	....	....	....	....	....	....	....	0	....	....	....	....	1	2	15	....	....	....	....	....	....	0
" 15....	81	68	74.25	....	....	....	....	....	....	....	0	....	....	....	....	1	3	20	....	....	....	....	....	....	0
" 16....	84	72	77.20	....	....	....	....	....	....	....	0	....	....	....	....	1	3	20	110	71	....	....	....	....	0
" 17....	79	70	75.00	....	....	....	....	....	....	....	0	....	....	....	....	2	2	20	....	....	....	....	....	....	0
" 18....	78	67	71.91	....	....	....	....	....	....	....	d.	....	....	....	....	d.	1	10	....	....	....	....	....	....	0
" 19....	82	68	74.95	....	....	....	....	....	....	....	....	....	....	....	....	....	d.	....	....	....	....	....	....	....	0
" 20....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0
" 21....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0
" 22....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0
" 23....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	d.

TABLE VIII. SUMMARY FOR TABLE VII.

	Toxoptera graminum.																					
Experiment No.	1	2	3	4	5	6	7	8	9	10	11B	12B	13B	14B	15B	16B	17B	18B	19B	20B	21B	22B	23B
Length of life	67	42	40	....	....	....	....	30	....	41	30	....	....	....	45	46	55	66	48	34	36	37	49
Total number of offspring	58	38	41	42	50	50	39	54	32	49	49	35	41	59	34	66	78	63	56	37	59	52	77
Period of reproduction	42	20	25	36	23	17	22	19	22	29	18	29	22	30	24	33	36	36	34	21	24	27	38
Number of moults	....	....	....	4	....	4	5	4	4	3	4	4	4	4	3	3	4	3	5	4	4	4	4
Age when reproduction begins, days	15	22	15	16	14	13	13	11	11	11	13	12	12	13	13	11	11	12	11	11	12	10	11

SUMMARY FOR TABLE VII.—CONCLUDED.

	Toxoptera graminum.																*Macrosiphum granaria.*						
Experiment No.	24B	25B	26B	27B	28	29B	30B	31B	32B	33B	34B	35B	36B	37B	Total.	Average.	38	39	40B	41B	42	Total.	Average.
Length of life	51	41	55	36	48	32	35	58	44	28	25	36	40	33	1,226	42.5	48	....	33	33	52	166	41.5
Total number of offspring	72	82	100	65	38	53	64	64	42	58	37	32	47	32	2,214	59.8	49	23	40	27	38	177	35.4
Period of reproduction	39	28	36	23	36	23	25	25	21	20	17	26	32	25	1,003	27.1	34	25	22	20	28	129	25.8
Number of moults	4	4	5	4	4	4	4	5	4	4	4	4	4	4	....	4.0	....	....	....	....	....	....	....
Age when reproduction begins, days	10	8	11	11	12	9	10	9	9	8	7	10	9	8	424	11.5	14	....	10	12	12	48	12.0
Average number of young produced daily by each individual during reproduction period															....	2.2	....	....	....	....	....	....	1.37

Mean temperature of laboratory from Janurary 6 to May 20, 1908, was 62.32°.

CONCLUSIONS.

Under conditions which obtained in the laboratory, the average length of life is, for *Toxoptera graminum*, 42.5 days; for *Macrosiphum granaria*, 41.5 days.

The average age when reproduction begins is, for *Toxoptera graminum*, 11.5 days; for *Macrosiphum granaria*, 12 days.

The average reproduction period is, for *Toxoptera graminum* 27.1 days; for *Macrosiphum granaria*, 25.8 days.

The average number of young is, for *Toxoptera graminum*, 59.8; for *Macrosiphum granaria*, 35.4.

The usual number of moults is, for *Toxoptera graminum*, 4.

PROGENY OF ONE INDIVIDUAL DURING THE SEASON.

Now, considering the reproductive period of the average green bug, based on the foregoing experiments, to be twenty-five days, and that reproduction begins on the seventh day and that the average daily offspring is two, we endeavored to ascertain the probable number of offspring during the season; that is, from April 1 to October 1. Accordingly Miss Jessie Smith, a competent accountant, by actual computation carefully performed, starting with a single female at seven days old, found that the progeny of this green bug, making no allowances for mishaps, would aggregate from month to month the following numbers of individuals:

First month, April	15,794
Second month, May	107,314,398
Third month, June	731,186,744,814
Fourth month, July	5,019,680,715,382,100
Fifth month, August	33,192,036,553,088,570,072
Sixth month, September	222,759,713,969,919,923,898,212

In this time six generations are completed and twenty-three generations in all are begun.

THE EFFECT ON WHEAT OF THE GREEN BUG, *Toxoptera graminum*, AS COMPARED WITH THE MORE COMMON GRAIN APHIS, *Macrosiphum granaria*.

1B.—*February 26 to March 11, 1908.*

February 26 twenty winged *Toxoptera graminum* and twenty winged *Macrosiphum granaria* were placed on wheat in separate breeding-cages. March 11 the *Toxoptera* wheat was dead; the *Macrosiphum* wheat was in good condition. Time, fourteen days. Both plants received the same care. See figure 24.

a *b*

FIG. 24. (a) Plant 14 days after the introduction of 20 adult *M. granaria*. (b) Plant 14 days after the introduction of *T. graminum*. See exp. 1b. The figure illustrates the greater destructiveness of *T. graminum* as compared with *M. granaria*. From photograph. (Original.)

2B.—*March 19 to March 30, 1908.*

March 19 twenty winged *Toxoptera graminum* and twenty winged *Macrosiphum granaria* were placed on wheat in separate breeding-cages. March 30 the *Toxoptera* wheat was dead, while the *Macrosiphum* wheat was in good condition. Time, eleven days. See figure 25.

3B.—*April 7 to April 23, 1908.*

April 7 twenty winged *Toxoptera graminum* and twenty winged *Macrosiphum granaria* were placed in separate breeding-cages on wheat. April 23 the *Toxoptera* wheat was dead, while the *Macrosipum* wheat was in good condition. Time sixteen days.

TWO COMMON GRAIN APHIDS FREQUENTLY MISTAKEN FOR THE GREEN BUG.

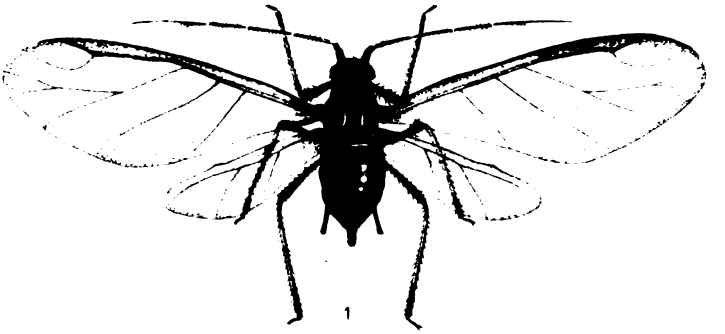
FIG. 1. English grain-louse, *Macrosiphum granaria*. Migratory form.

FIG. 2. Wingless form of the same.

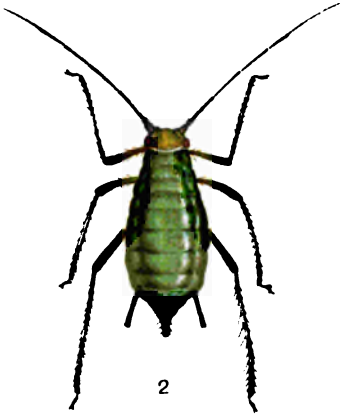
FIG. 3. European grain-louse, *Siphocoryne avenæ*. Wingless form.

FIG. 4. Migratory form of same.

PLATE II

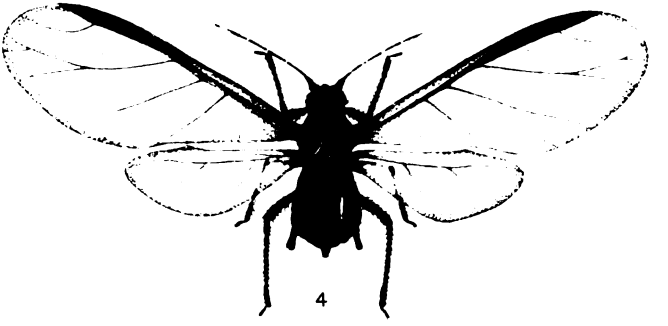


1



2

3



4

SIBYL BETTS

A. HOEN & CO., BALTIMORE

4B.—*April 14 to May 4, 1908.*

April 14 twenty winged *Toxoptera graminum* and twenty winged *Macrosiphum granaria* were placed in separate breeding-cages on wheat. April 28 the *Toxoptera* wheat was yellow, while *Macrosiphum* wheat was still green. May 4 the *Toxoptera* wheat was dead; the *Macrosiphum* wheat was in good condition. Time, twenty days.

5B.—*April 24 to May 12, 1908.*

April 24 twenty winged *Toxoptera graminum* and twenty winged *Macrosiphum granaria* were placed on wheat in separate breeding-cages. May 12 the *Toxoptera* wheat was dead; the *Macrosiphum* wheat was in good condition. Time, eighteen days. See figure 26.

6B.—*May 4 to May 20, 1908.*

May 4 twenty winged *Toxoptera graminum* and twenty winged *Macrosiphum granaria* were placed on wheat in separate breeding-cages. May 20 the *Toxoptera* wheat was dead and all bugs starved to death, while the *Mocrosiphum* wheat was in good condition and the *Macrosiphum* were flourishing. Time, sixteen days.

7B.—*May 6 to May 19, 1908.*

May 6 twenty winged *Toxoptera graminum* and twenty winged *Macrosiphum granaria* were placed on plants in separate breeding-cages. May 19 the *Toxoptera* wheat was dead, while the *Macrosiphum* wheat was in good condition. Time, fourteen days.

a *b*

FIG. 25. (*a*) Plant 11 days after the introduction of 20 adult *M. granaria*. (*b*) Plant 11 days after the introduction of *T. graminum*. See exp. 2*b*. The figure illustrates the greater destructiveness of *T. graminum* as compared with *M. granaria*. From photograph. (Original.)

a *b*

FIG. 26. (*a*) Plant 18 days after the introduction of 20 adult *M. granaria*. (*b*) Plant 18 days after the introduction of *T. graminum*. See exp. 5*b*. The figure illustrates the greater destructiveness of *T. graminum* as compared with *M. granaria*. From photograph. (Original.)

In the experiments with *Toxoptera graminum* and *Macrosiphum granaria* to show the effect on wheat, it was found that on an average of fifteen days the *Toxoptera graminum* killed the wheat on which they were placed, while the *Macrosiphum granaria*, in the same time and under the same conditions, inflicted only slight injury. In both cases the wheat was the same, having been planted at the same time and being kept side by side in the laboratory and receiving the same care. The conditions as to the number of individuals of each species used and the number of stalks of wheat used in each experiment were also the same.

The experiments show that although *Toxoptera graminum* is smaller in size than *Macrosiphum granaria*, it is much more destructive to the host-plant.

TIME AND MODE OF DEVELOPMENT OF TRUE SEXES.

The field and laboratory study of the forms just described has brought out some rather interesting facts in the structure and development of this aphid. These have been brought together by Glenn, to whose careful observation this information is largely due.

THE TRUE SEXES.

These experiments fall into three groups: (1) To ascertain the origin of the sexual forms; (2) to ascertain the length of life of and the number of eggs laid by the true female.

About forty experiments were carried on to ascertain the origin

of the sexual forms. They were conducted in the following manner:

Single wingless and winged forms were isolated on a plant. When several young were produced the adult was removed and the young were reared and the forms into which they developed noted. When they became adults all were removed but one. The offspring of this one were reared the same way.

After the time for the sexual forms was past all these experiments were discontinued except three, which were kept up throughout the winter to the present time, but in a little different manner, for the purpose of ascertaining the length of the period of development at different seasons of the year in the laboratory, the relative number of winged and wingless forms, and whether or not winged forms give birth to winged forms, whether winged forms are produced at regular intervals or not, etc. The only change in the manner of conducting the experiments was in that instead of removing all the adults but one each time and getting the offspring of a single individual, all the adults were preserved until collectively they had produced several young. In most cases when there were both winged and wingless forms in the part of a generation reared, either all the winged forms or all the wingless forms were removed before saving the young to rear. This is indicated in the column headed "Parent."

Experiments Nos. 14 and 15 are the only ones in which a sexual form was bred. Nos. 16 and 17 were not started until December 14, 1907. The following charts give the data in tabulated form:

TABLE IX. DATA OF THE FIRST-BORN OF SUCCESSIVE GENERATIONS OF *TOXOPTERA GRAMINUM*, FROM DECEMBER 14, 1907, TO MAY 16, 1908.

EXPERIMENT NO. 16, UPPER LABORATORY.

No. of generations.	When born.		When matured.		Time in days.			Mean tem.	Number reared.			Parent.
	First.....	Last.....	First.....	Last.....	Max.....	Min.....	Average.....		Apterous.	Winged.....	Male.....	
1	Dec. 14	Dec. 14	Dec. 28	Dec. 28	14	14	14	65	2	1	....	Apt. fem.
2	Jan. 14	Jan. 14	Jan. 27	Jan. 29	15	13	14	57	2	....	....	" "
3	" 28	" 30	Feb. 11	Feb. 11	14	12	13	59	2	....	....	" "
4	Feb. 11	Feb. 11	" 22	" 25	14	11	12.5	56	3	....	....	" "
5	" 22	" 25	Mar. 3	Mar. 6	10	10	10	61	7	5	....	" "
6	Mar. 6	Mar. 7	" 17	" 20	13	11	12	56	2	2	....	" "
7	" 18	" 19	" 28	" 31	12	10	11	64	5	1	....	" "
8	" 28	" 30	Apr. 7	Apr. 8	10	9	9.5	64	3	5	....	" "
9	Apr. 8	Apr. 8	" 17	" 18	10	9	9.5	64	6	1	....	" "
10	" 17	" 18	" 25	" 25	8	7	7.5	70	4	....	....	" "
11	" 26	" 25	May 5	May 7	12	10	11	63	2	1	....	" "
12	May 5	May 8	" 15	" 16	10	8	9	74	7	....	....	Apt. and wgd.
Total number reared.....					....	....	.....	....	45	16	....	.....
Average development period.....					....	....	11+	....	....	....	....	.....

TABLE X. DATA OF THE FIRST-BORN OF SUCCESSIVE GENERATIONS OF *TOXOPTERA GRAMINUM*, FROM DECEMBER 14, 1907, TO MAY 18, 1908.

EXPERIMENT NO. 17, UPPER LABORATORY.

No. of generation.	When born.		When matured.		Time in days.			Mean tem.	Number reared.			Parent.
	First.	Last.	First.	Last.	Max.	Min.	Average.		Apterous.	Winged.	Male.	
1	Dec. 14	Dec. 14	Dec. 28	Dec. 28	14	14	14	65	2	1	....	Apt. fem.
2	Jan. 14	Jan. 14	Jan. 27	Jan. 29	15	13	14	68	2	....	....	" "
3	" 28	" 30	Feb. 11	Feb. 13	14	14	14	57	3	....	....	" "
4	Feb. 11	Feb. 13	" 24	" 26	13	13	13	65	6	....	....	" "
5	" 24	" 26	Mar. 7	Mar. 7	12	10	11	57	3	....	....	" "
6	Mar. 7	Mar. 8	" 19	" 20	12	12	12	64	4	5	....	
7	" 19	" 20	" 30	" 30	11	10	10.5	64	....	....	....	Apt. and wgd.
8	" 29	" 30	Apr. 7	Apr. 9	10	9	9.5	64	3	10	....	Apt. fem.
9	Apr. 9	Apr. 9	" 18	" 18	9	9	9	64	10	....	....	Wgd. fem.
10	" 18	" 18	" 25	" 25	7	7	7	71	12	....	....	Apt. fem.
11	" 25	" 25	May 6	May 7	12	11	10.5	68	6	5	....	" "
12	May 8	May 8	" 18	" 18	10	10	10	77	6	....	....	Wgd. fem.
Total number reared									57	21		
Average development period							11½					

TABLE XI. DATA OF THE FIRST-BORN OF SUCCESSIVE GENERATIONS OF *TOXOPTERA GRAMINUM*, FROM OCTOBER 28, 1907, TO MAY 12, 1908.

EXPERIMENT NO. 14. UPPER LABORATORY.

No. of generation.	When born.		When matured.		Time in days.			Mean tem.	Number reared.			Parent.
	First.	Last.	First.	Last.	Max.	Min.	Average.		Apterous.	Winged.	Male.	
1	....	....	....	....	....	....	....	....	1	....	....	Not observed.
2	Oct. 25	Oct. 29	Nov. 8	Nov. 9	14	11	12.5	69	1	....	2	Apt. fem.
3	Nov. 8	Nov. 9	" 18	" 18	10	9	9.5	64	6	....	....	" "
4	" 18	" 19	" 28	" 30	11	10	10.5	65	1	2	....	
5	Dec. 2	Dec. 5	Dec. 17	Dec. 17	15	12	13.5	53	2	....	....	Wgd. fem.
6	" 17	" 20	Jan. 6	Jan. 8	20	19	19.5	61	4	....	....	Apt. fem.
7	Jan. 8	Jan. 8	" 20	" 21	13	12	12.5	59	5	....	....	" "
8	" 20	" 21	Feb. 5	Feb. 5	16	15	15.5	57	1	....	....	" "
9	Feb. 6	Feb. 6	" 17	" 18	12	11	11.5	61	3	....	....	
10	" 17	" 18	" 29	Mar. 4	15	12	13.5	61	5	5	....	Wgd. fem.
11	Mar. 6	Mar. 7	Mar. 14	" 16	9	8	8.5	64	13	....	....	Apt. fem.
12	" 14	" 16	" 25	" 30	14	11	12.5	65	9	1	....	Wgd. and apt. f.
13	" 25	" 30	Apr. 2	Apr. 6	8	7	7.5	65	8	....	....	Apt. fem.
14	Apr. 2	Apr. 4	" 14	" 16	12	12	12	68	7	....	....	" "
15	" 14	" 16	" 22	" 24	8	8	8	69	24	....	....	" "
16	" 22	" 22	May 1	May 3	11	9	10	64	10	....	....	
17	May 1	May 2	" 12	" 13	11	11	11	66	3	....	....	....
Total number reared									93	8	2	
Average time							11¾					

TABLE XII. DATA OF THE FIRST-BORN OF SUCCESSIVE GENERATIONS OF *TOXOPTERA GRAMINUM*, FROM NOVEMBER 1, 1907, TO JANUARY 18, 1908.

EXPERIMENT No. 15. UPPER LABORATORY.

No. of generation	When born. First.	When born. Last.	When matured. First.	When matured. Last.	Time in days. Max.	Time in days. Min.	Time in days. Average.	Mean tem.	Number reared. Apterous.	Number reared. Winged.	Number reared. Male.	Parent.
1									1			
2	Nov. 1	Nov. 12	Nov. 18	Nov. 19	17	7	12	61	3	...	1	Apt. fem.
3	" 18	" 18	" 28	" 28	10	10	10	65	4			" "
4	" 30	Dec. 2	Dec. 16	Dec. 16	17	14	15.5	52	3			" "
5	Dec. 16	" 16	" 30	" 30	14	14	14	57	4			" "
6	" 30	" 30	Jan. 18	Jan. 18	19	19	19	65	1			" "
Total number reared									17		1	
Average development period							14.1					

Total number reared: Apterous females 212
Winged females 45
Males 3
Total 260
Average development period, 11.7 days.

CONCLUSIONS DRAWN FROM THE EXPERIMENTS OF 1907.

1. The males are the offspring of the wingless agamic females.

2. Wingless agamic females may produce both males and viviparous forms.

In experiment No. 14, between October 25 and October 29, 1907, an apterous female gave birth to young, three of which were reared. On November 4 one was getting wing-pads and on the 8th was a matured male. On the 8th another had wing-pads and on the 9th was a matured male. The third one matured on the 8th and had five young. So in this case an apterous agamic female and two males were reared from the same apterous agamic female.

In experiment No. 15, a wingless agamic female was placed on a plant November 1, on the 13th all but four were removed. On the 18th three of them were adult wingless viviparous females, and on the 19th the fourth was a fully developed male.

In none of the other experiments did I rear any sexual forms. Had the experiments been started a month earlier no doubt both males and true females would have been secured in abundance, for they were abundant on our stock at the time these experiments were begun.

3. Under temperature condition which prevailed in the laboratory, the season of the year and the condition of food-plant apparently influenced the length of the development period more than the temperature.

4. Under conditions which obtained in the laboratory, about 82½ per cent. are wingless and 17½ per cent. winged.

5. The abundance or scarcity of food supply did not seem to increase or diminish the number of winged forms.

6. There may be winged forms in successive generations.

7. Winged forms may produce winged forms directly.

The experiments tabulated above do not show this, but rather the contrary; but I found this to be true in several instances in the other experiments.

In experiment No. 28 I reared a single young, born from a winged migrant November 25; on December 9 it was a matured winged migrant. One young, born December 9 from this winged migrant, matured into a winged migrant December 23.

EXTREMES OF TEMPERATURE.

The lowest temperature at which green bugs reared in the field produced offspring was maximum 36° F., minimum 4° F., in experiment No. 2, January 29.

Glenn, in his experiments under artificial conditions, using a chamber heated by electricity, found that the green bug produced offspring between temperatures of 103° F. and 65° F.; both adults and offspring soon perished under such conditions. Temperatures of 107° F. are fatal to the green bug, though food supply is abundant.

Chesky and the author, under natural conditions, observed offspring which had appeared during July 8, maximum 95° F., minimum 72° F., from a number of experiments then under observation.

FOOD PLANTS OF *Toxoptera graminum* R.

Rondani, 1852:

Oats (*Avena sativa* and *elatior*).
Wheat (*Triticum vulgare*).
Spelt (*Triticum spelta*).
Couch grass (*Triticum repens*).
Wall barley (*Hordeum murinum*).
Soft chess (*Bromus mollis*).
Corn (*Zea mays*).

Passerini, 1863:

Sorghum (*Andropogon*).

Giac Del Guercio, 1900:

Common barley (*Hordeum vulgare*).
Orchard-grass (*Dactylis glomerata*).
Brome-grass or Chess grass (*Bromus* sp.).
Common darnel or rye grass (*Lolium perenna*).

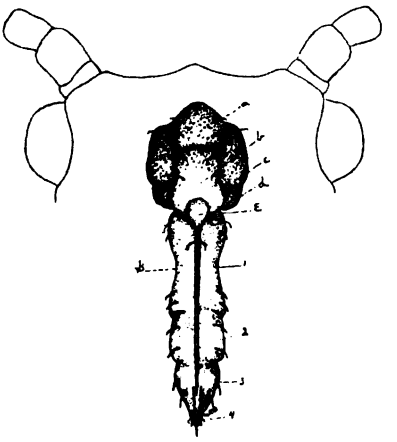


FIG. 26a. *Toxoptera graminum*. Mouth parts of wingless form, cephalic view. (*a*) Clypeus. (*b*) Labrum. (*c*) Mandibular lamina. (*d*) Maxillary lamina. (*e*) Reservoir for Setæ. (*g*) Mandibular Setæ with Maxillary Setæ between. 1, 2, 3 and 4 are joints of Labrum. Greatly magnified. (Original.)

Ainslee and Phillips, 1907:

Marsh foxtail (*Alopecurus geniculatus*).

Webster, Chesky, 1907:

Crab-grass (*Syntherisma sanguinalis*).

To which we add:

Blue-grass (*Poa prætensis*). In the field as late as January, 1908. Also noted by Gillette and Ainslee, 1907.

"Toadstools." At different times in the laboratory boxes, green bugs were found with beaks inserted in "toadstools." Abundance of wheat was on hand for them to feed upon.

Rye (*Secale cereale*), upon which they lived and reproduced.

DESCRIPTION OF SPECIES.

APTEROUS FEMALE.—Length 1 to 1.8 mm. Color yellowish green and slightly pruinous, the median line darker green, the head and prothorax somewhat paler than the rest of the body; eyes black; antennæ black, the two basal joints and more or less of the third joint at base yellowish; legs yellowish, the tibiæ brownish toward the apex, tarsi black; nectaries greenish and frequently with a dusky tinge, their apex black; tail dusky. The general color of the larvæ and pupæ is like that of the apterous female; wing-pads of pupa dusky to black; antennæ slender and about one-half the length of the body; nectaries slightly tapering, reaching to or slightly beyond the end of the body; tail slender, somewhat constricted about the middle, and about two-thirds the length of the nectaries; there is a distinct fleshy tubercle each side of the prothorax and similar tubercles along both sides of the abdomen.

MIGRATORY FEMALE.—Expanse of wings 5 to 7 mm., length of body 1.5 to 2 mm. General coloration of the abdomen as in the apterous forms; head brownish yellow; the eyes brown; antennæ, thoracic lobes, the posterior margin of the scutellum and the sternal plate black; the two basal joints of the antennæ yellowish green; legs yellow, the femora more or less dusky, the posterior pair dark-

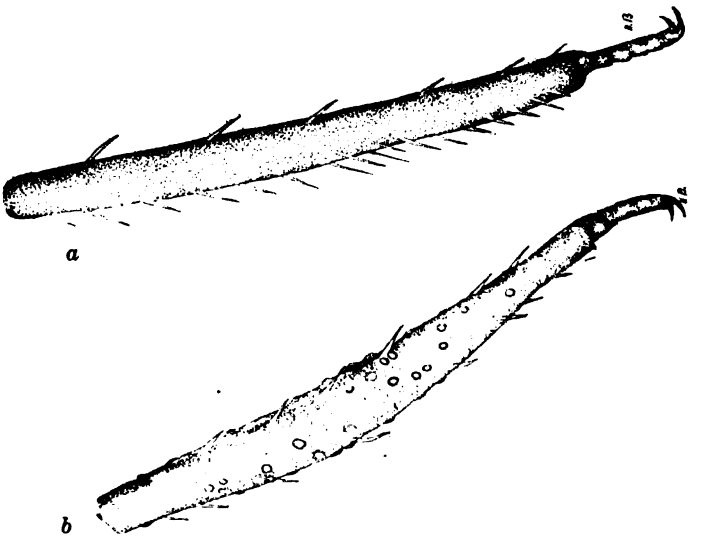


FIG. 27. *Toxoptera graminum.* Hind tibia and tarsi of (*a*) agamic form, and (*b*) oviparous form.

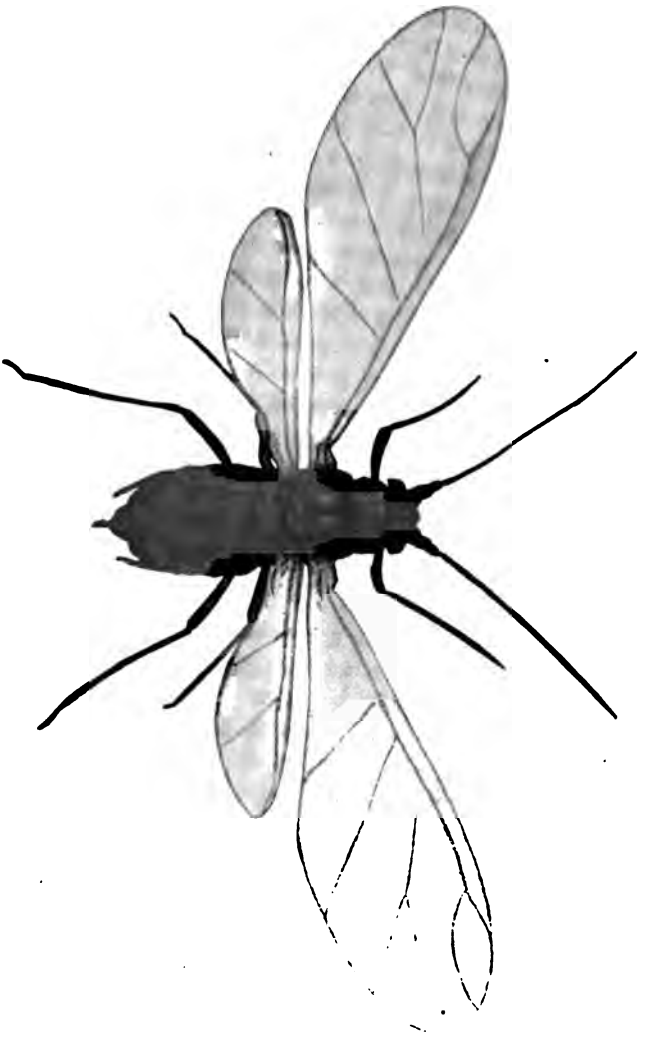


FIG. 27a. Winged agamic female, showing normal wings. Greatly enlarged. From photograph. (Original.)

est; apex of tibiæ and the tarsi black; nectaries and tail yellowish, the latter changing gradually to dusky or black toward the end; wings transparent; costa and subcosta yellow; the stigma somewhat paler, its inner edge and the veins black; third discoidal vein with but one fork; antennæ long and slender, reaching nearly to the end of the body, the third joint provided with three to seven sensoria; nectaries, tail, and lateral tubercles as in the apterous females.

The above is by Pergande,[1] to which the writer adds the following:

OVIPAROUS FEMALE.—The oviparous female, according to frontispiece and the writer's observations, conforms to the above description for the apterous viviparous female, except that the antennæ extend beyond the middle of the body and the nectaries do not extend beyond the end of the abdomen. The hind tibiæ are conspicuously enlarged and bear from thirty to fifty sensoria, resembling those found on the antennæ of the male and the winged migrant. The oviparous females are also to be distinguished from the viviparous form by their more oval and elongated, swollen, often much darker green bodies, through which the lighter colored ova are frequently to be seen (see figs. 27, 30). Egg about 0.5 mm. in length, 0.2 mm. in breadth, light green, glossy, translucent, frequently changing to black after a day or so.

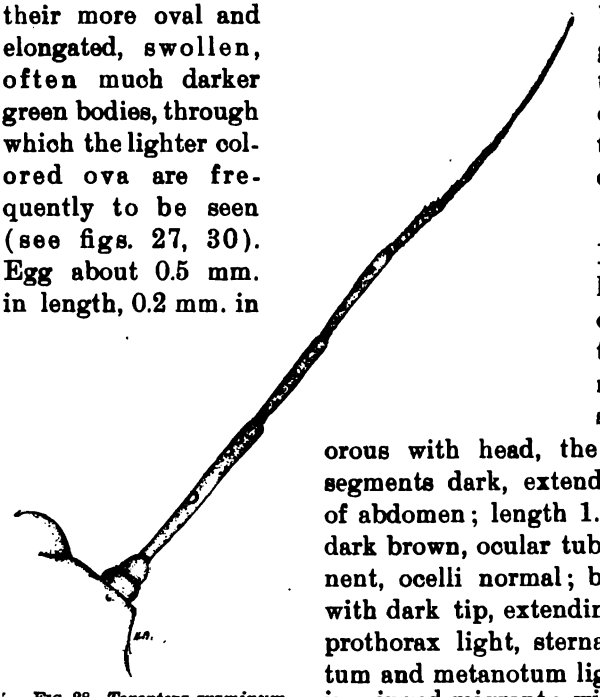


FIG. 28. *Toxoptera graminum*. Antenna of the male, showing segments which bear sensoria.

THE MALE.—Head light yellowish green, the cuticle smoky; the base of antennæ and first two segments concolorous with head, the remaining four segments dark, extending beyond end of abdomen; length 1.6 to 2 mm., eyes dark brown, ocular tubercles not prominent, ocelli normal; beak concolorous, with dark tip, extending to mesocoxæ; prothorax light, sternal plate, mesonotum and metanotum lighter brown than in winged migrant; wing venation as in migrant, with frequent variation, show-

1. Div. Ent., Bul. No. 38, new series. U. S. Dept. Agr.

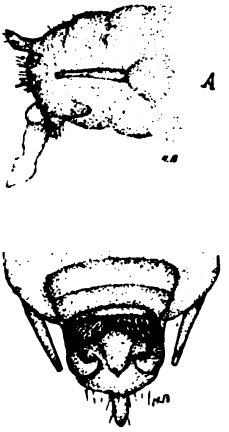


FIG. 29. *Toxoptera graminum.* Male. Caudal extremity, lateral (*A*), and ventral views. Greatly magnified. (Original.)

FIG. 30. *Toxoptera graminum.* Oviparous female. Greatly enlarged. (Original.)

ing one wing with third discoidal vein simple; total wing expanse 3.5 to 4.5 mm.; legs light yellow, excepting distal half of femur dark, distal end of tibiæ and tarsi black; abdomen light green, the median line darker green; nectaries concolorous with abdomen at base, darker distally, extending to or slightly beyond the end of abdomen; genitalia light brown (see fig. 29 for structure); length of body 1.5 to 2 mm. The males are readily distinguished by their smaller bodies, almost uniformly light yellowish-green color, and length of antennæ, which extend beyond tip of abdomen. The winged aphids, among Aphididæ, have longer antennæ than the migrant or the wingless females of some species. In this respect the male of this species simply conforms.

The observations on this experiment was kept by Glenn and these follow.

FORMS OF *Toxoptera graminum.*

Since the *Toxoptera graminum* appeared in the spring of 1907 they have been under constant observation in our laboratory, and we have had an opportunity to note carefully all the forms except the stem mother. Ordinarily the only forms present are the apterous agamic females and the winged migrants; but at the time when the sexual forms are being produced marked variations take place, and aside from the forms above mentioned, and the males and the true females, three more or less distinct intermediate forms appear.

FIG. 31. *T. graminum.* Presexual form, showing the undeveloped character of the wings. From photograph. (Original.)

The chief characteristics which distinguish the different forms are: The number of sensoria on the third, fourth and fifth joints of the antennæ and the hind tibiæ, the presence, absence, or degree of prominence of the ocelli, the shape of the hind tibiæ, the contents of the body, and the presence, absence, or degree of development of the wings.

Based on these characteristics I have, for the purpose of this discussion, named eight forms, five of which are distinct and three of which are intermediate forms. They are as follows:

1. Apterous agamic females.
2. Winged agamic females.
3. Winged intermediate females, resembling the winged agamic females in antennal characteristics.
4. Winged intermediate females, resembling the true females in antennal characteristics.
5. Apterous intermediate females.
6. True females.
7. Males.
8. Stem mothers.

In the following tables the characteristics of these forms, with the exception of the stem mother, are given in tabular form.

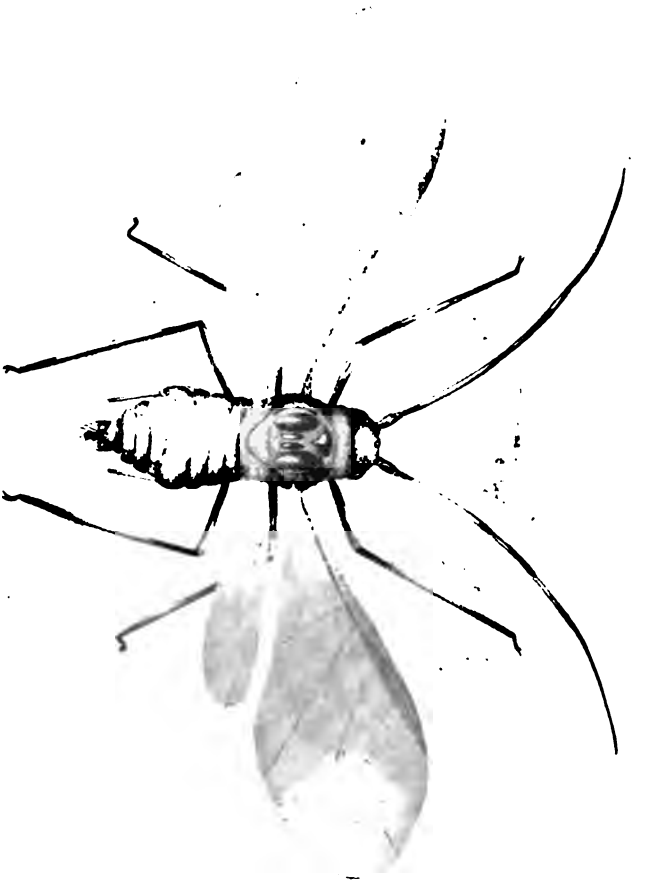


FIG. 32. *Toxoptera graminum*. Male form of the "green bug." Greatly enlarged. (Original.)

FIG. 33. *Toxoptera graminum.* Oviparous female, ventral view, showing eggs, extruded and within body. Greatly magnified, from micro-photograph. (Original.)

FIG. 34. *Toxoptera graminum.* Oviparous female. Caudal extremity, ventral view. Greatly magnified. (Original.)

TABLE XIII. 1.—Wingless agamic females.

Specimen No.....	Sensoria of antennæ. III.	IV.	V.	VI.	Sensoria of tibiæ.	Ocelli.....	Remarks.
1	0 0	0 0	1 1	1+6 1+5	0 0	0	Young in various stages of development visible in body.
2	0 0	0 0	1 1	1+ 1+	0 0	0	
3	0 0	0 0	1 1	1+5 1+6	0 0	0	
4	0 0	0 0	1 1	1+5 1+	0 0	0	
5	0 0	0 0	1 1	1+4 1+	0 0	0	
6	0 0	0 0	1 1	1+6 1+5	0 0	0	
7	0 0	1 1	1+6 1+6	....	0 0	0	Immature.

TABLE XIV. 2.—Winged agamic females.

Specimen No.....	Sensoria of antennæ. III.	IV.	V.	VI.	Sensoria of tibiæ.	Ocelli.....	Remarks.
1	5 4	0 0	1 1	1+ 1+	0 0	3	Young visible in body. See fig. 35a.
2	7 6	0 0	1 1	1+ 1+	0 0	3	
3	6 5	0 0	1 1	1+ 1+	0 0	3	
4	6 5	0 0	1 1	1+ 1+	0 0	3	
5	6 4	0 0	1 1	1+ 1+	0 0	3	No young visible.
6	5 5	0 0	1 1	1+ 1+	0 0	3	Young visible in body.
7	5 5	1 0	1 1	1+ 1+	0 0	3	
8	5 6	0 0	1 1	1+ 1+	0 0	3	
9	5 6	0 0	1 1	1+ 1+	0 0	3	
10	5 5	0 0	1 1	1+ 1+	0 0	3	

TABLE XV. 3.—Winged intermediate female, resembling the winged agamic form in antennal characteristics.

Individual No.....	Sen. of an. joints. III.	IV.	V.	VI.	Post. tibiæ. Sen.	Shape.	No. of ocelli.....	Contents of body.	Wings.
1	4 4	0 0	1 1	1+ 1+	16 13	Thick...	3	2 young.	Very small, venation nearly absent.
2	3 3	0 0	1 1	1+3 1+5	11 ..	Thick...	3	6 young.	Venation weak and irregular.
3	4 4	0 0	1 1	1+ 1+	39 32	Thick...	3	2 young.	Wings small, venation weak, discoidals simple.
4	3 —	0 0	1 1	1+ 1+	11 10	Thick...	3	6 young.	Third discoidals unbranched.
5	5 4	0 0	1 1	1+ 1+	0 0	Slender.	3	2 young.	Rudimentary.
6	5 2	0 0	1 1	1+ 1+	0 0	Slender.	3	7 young.	Rudimentary. See pl. VII, fig. 2.
7	4 5	0 0	1 1	1+ 1+	14 ..	Thick...	3	2 young.	Wings small, third discoidals simple in one wing; second and third united at their base in other.
8	4 4	0 0	1 1	1+ 1+	18 17	Thick...	3	6 eggs. 6 young.	Wings small, discoidals simple. Pl. IX, fig. 6.
9	3 4	0 0	1 1	1+ 1+	19 15	Thick...	3	2 eggs. 7 young.	Wings small, venation much weakened. Pl. VIII, fig. 3.
10	5 5	0 0	1 1	1+ 1+	4 5	Slender.	3	3 eggs. 4 young.	Third discoidals irregular.

TABLE XVI. 4.—Winged intermediate females, resembling the true females in antennal characteristics.

Individual No.....	Sen. of ant. joints. III.	IV.	V.	VI.	Post. tibiæ. Sen.	Shape.	Ocelli.....	Contents of body.	Wings.
1	0 0	0 0	1 1	1+ 1+	30 21	Thick...	3 small.	6 young.	Small, crumpled.
2	0 0	0 0	1 1	1+ 1+	66 60	Thick...	3 small.	5 young.	Very small, crumpled.
3	0 0	0 0	1 1	1+ 1+	5 9	Thick...	?	5 young.	Small, crumpled.
4	0 0	0 0	1 1	1+ 1+	31 40	Thick...	3	4 young.	Rudimentary.
5	0 0	0 0	1 1	1+ 1+	25 23	Thick...	3	7 young.	Rudimentary.
6	0 0	0 0	1 1	1+ 1+	41 30	.....	?	4 young.	Rudimentary.
7	0 0	1 1	1 1	1+ 1+	50 45	Thick...	3	4 young.	Rudimentary.
8	0 0	0 0	1 1	1+ 1+	60 30	Thick...	0	5 young.	Rudimentary. See Pl. VIII, fig. 1.
9	0 0	0 0	1 1	1+ 1+	8 12	Thick...	?		
10	0 0	0 0	1 1	1+ 1+	31 22	Thick...	0	1 egg. 4 young.	Rudimentary. See Pl. IX, fig. 5.

PLATE VIII.

Fig. 1.

Fig. 2.

Fig. 3.

FIGS. 1 and 2. Transitional forms, showing rudimentary wings.

FIG. 3. Winged form, producing both living young and winter eggs. The viviparous young are readily distinguished by the black eye spots.

PLATE IX.

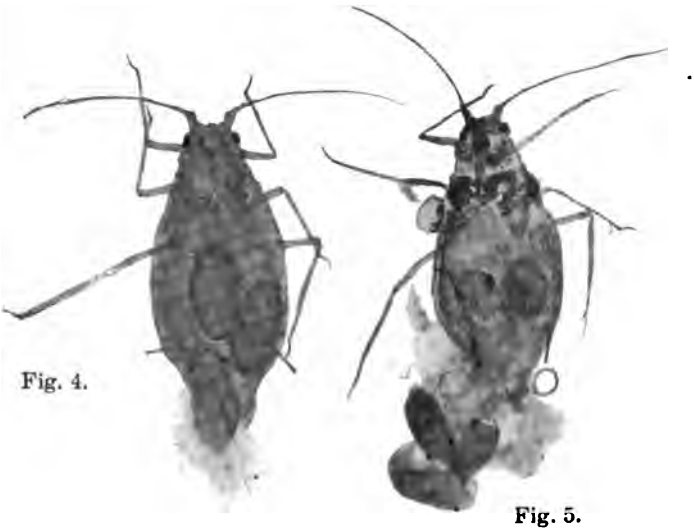


Fig. 4.

Fig. 5.

Fig. 6.

FIG. 4. Wingless forms, being both oviparous and viviparous.

FIG. 5. The same phenomenon is illustrated in both figures, the eggs are clean, the living young distinguished by black eye spots.

FIG. 6. A winged form, showing same condition.

TABLE XVII. 5.—Apterous intermediate female.

Individual No.....	Sen. of ant. joints. III.	IV.	V.	VI.	Post tibiæ. Sen.	Shape.	Ocelli.	Contents of body.	Wings.
1	0 / 0	0 / 0	1 / 1	1+ / 1+	24 / ..	Thick...	0	4 young.	None.
2	0 / 0	0 / 0	1 / 1	1+ / 1+	30 / ..	Thick...	0 / 0	2 eggs. 3 young.	None.
3	0 / 0	0 / 0	1 / 1	1+ / 1+	21 / 17	Thick...	0	3 young.	None.
4	0 / 0	0 / 0	1 / 1	1+ / 1+	20 / ..	Thick...	0	4 young.	None.
5	0 / 0	0 / 0	1 / 1	1+ / 1+	27 / 15	Thick...	0 / 0	5 eggs. 2 young.	None.
6	0 / 0	0 / 0	1 / 1	1+ / 1+	10 / 9	Thick...	0	3 young.	None.
7	0 / 0	0 / 0	1 / 1	1+ / 1+	.. / ..	Thick...	0 / 0	1 egg. 2 young.	None. See plate IX, fig. 4.
8	0 / 0	0 / 0	1 / 1	1+ / 1+	30 / 25	Thick...	0 / 0	2 young.	None.

TABLE XVIII. 6.—True female.

Individual No.....	Sensoria of antennæ joints. III.	IV.			Post. tibiæ. Sen.	Shape.	Ocelli.....	Contents of body..	Wings.
11	0 / 0	0 / 0	1 / 1	1+ / 1+	35 / ..	Thick...	0	7 eggs...	None.
12	0 / 0	0 / 0	1 / 1	1+ / 1+	30 / 35	Thick...	0	7 eggs...	None.
13	0 / 0	0 / 0	1 / 1	1+ / 1+	55 / 40	Thick...	0	3 eggs...	None.
14	0 / 0	0 / 0	1 / 1	1+ / 1+	.. / ..	Thick...	0	3 eggs...	None.
15	0 / 0	0 / 0	1 / 1	1+ / 1+	.. / ..	Thick...	0	3 eggs...	None.
16	0 / 0	0 / 0	1 / 1	1+ / 1+	30 / ..	Thick...	0	4 eggs...	None.
17	0 / 0	0 / 0	1 / 1	1+ / 1+	35 / 35	Thick...	0	5 eggs...	None.
18	0 / 0	0 / 0	1 / 1	1+ / 1+	46 / 35	Thick...	0	7 eggs...	None.
19	0 / 0	0 / 0	1 / 1	1+ / 1+	35 / 33	Thick...	0	5 eggs...	None.
20	0 / 0	0 / 0	1 / 1	1+ / 1+	50 / 45	Thick...	0	6 eggs...	None.

TABLE XIX. 7.—Male.

Individual No.....	Sensoria of antennæ joints.				Post. tibiæ.		Ocelli.....		Wings.
	III.	IV.	V.	VI.	Sen.	Size.			
11	15 20	12 9	13 14	1+ 1+	.. ..	Slender.	3	.....	Normal.
12	14 14	12 11	.. 14	... 1+	.. ..	Slender.	3	.....	Normal.
13	22 18	11 16	14 12	1+5 1+	.. ..	Slender.	3	.....	Normal.
14	14 18	13 14	12 12	1+ 1+6	.. ..	Slender.	3	.....	Normal.
15	14 12	15 15	15 17	1+6	.. ..	Slender.	3	.....	Normal.
16	16 14	12 11	10 13	1+ 1+	.. ..	Slender.	3	.....	Normal.
17	17 14	15 14	11 12	1+ 1+	.. ..	Slender.	3	.....	Normal.
18	15 17	14 13	12 13	1+ 1+	.. ..	Slender.	3	.....	Normal.
19	15 15	.. 12	.. 9	... 1+	.. ..	Slender.	3	.....	Normal.
20	.. ..	.. ..	.. ..	... ...	.. ..	.....	.....	.....	——

TABLE XX. SUMMARY of Tables XIII to XIX.

Form.....	Sen. of ant. joints.				Post. tibiæ.		Ocelli.....	Contents of body.	Wings.
	III.	IV.	V.	VI.	Sen.	Shape.			
1	0	0	1	1+	0	Slender.	0	Young.	None.
2	4–7	0	1	1+	0	Slender.	3	Young.	Present, normal.
3	2–5	0	1	1+	0–39	Thick or slender.	3	Young and eggs.	Small or rudimentary.
4	0	0	1	1+	5–66	Thick...	0–3	Young and eggs.	Rudimentary or crumpled.
5	0	0	1	1+	9–30	Thick...	0	Young and eggs.	None.
6	0	0	1	1+	30–55	Thick...	0	Eggs.	None.
7	12–22	9–16	9–17	1+	0	Slender.	3	.....	Normal.

It will be seen from the foregoing tables that all these forms agree in having a single (large) sensorium on the sixth joint of the antennæ with a cluster of from four to six smaller ones about its margin, in having one (large) terminal sensorium on the fifth joint, and, with the exception of the males, in having no sensoria on the fourth joint. In all the other characteristics above considered there are marked differences.

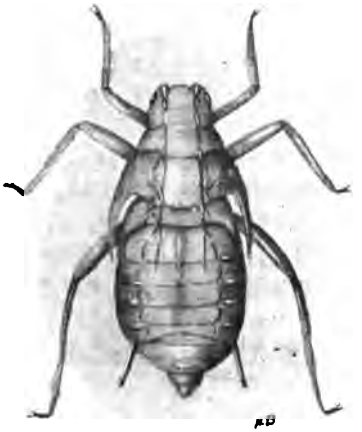


FIG. 35. Pupa of winged "green bug." Greatly enlarged. (Original.)

The apterous agamic female has no sensoria on the third joint of the antennæ, no sensoria on the hind tibiæ, no ocelli, has the hind tibiæ slender, and young in various stages of development are plainly visible in the body when mounted under a cover glass.

The winged agamic female has from four to seven sensoria on the third joint of the antennæ, has none on the hind tibiæ, three prominent ocelli, the hind tibiæ are more slender than in the apterous agamic form, the wings are normal, and young are plainly visible in the body under the microscope.

In these two forms the characteristics are surprisingly stable throughout the greater part of the year when we consider the great variations which suddenly occur in the fall when the intermediate and sexual forms are being produced.

The intermediate forms, though I have divided them into three classes, present nearly all gradations between the agamic and the oviparous forms.

The winged intermediate form, resembling the winged agamic form in antennal characteristics, has from two to five sensoria on the third joint of the antennæ. The hind tibiæ vary in form; they may be thickened, as in the true female, or be slender, as in the winged agamic form. When the tibiæ are thickened they possess from none to thirty-nine sensoria. This form has three ocelli, nearly or quite as prominent as in the winged agamic female. The body in some individuals contains only young, but in others both young and winter eggs. The wings are reduced; in some cases only one branch of the third discoidal is lacking, in others the wings are crumpled or rudimentary.

The winged intermediate form, resembling the true female in antennal characteristics, is similar to the one above described, except that the resemblance to the true female is more marked. There are no sensoria on the third joint of the antennæ. The posterior tibiæ are all thickened and have from five to sixty-six sensoria, the ocelli are usually inconspicuous or wanting, the body may have only young or both eggs and young, and the wings are greatly reduced, being in most cases only rudimentary.

The apterous intermediate form resembles the true female in all external characteristics, but is distinguished from the true female by the fact that the body contains only young or both young and eggs. It is, as yet, an open question with us as to whether both winter eggs and young are produced by the same ovary.

The winged intermediate forms stand between the winged agamic form and the true female, and the apterous intermediate form stands between the apterous agamic form and the true female.

The true female resembles the apterous agamic form in external characteristics, except that in the true female the hind tibiæ are conspicuously thickened and possess from thirty to fifty-five sensoria. The body is more robust than in the viviparous forms and the eggs showing through the body-wall give the body a lighter color. The bodies of all the intermediate forms are robust, as in the true female, but are not so light a green owing to the fact that the body contains young as well as eggs.

The male resembles in a general way the winged agamic form, but is smaller, the abdomen does not exceed the thorax in width, and is nearly uniform in width throughout its length. The third joint of the antennæ bears from twelve to twenty-two sensoria, the fourth from nine to sixteen, the fifth from nine to twenty-seven.

The stem mother has not been reared as yet and her characteristics cannot be given.

ORIGIN AND RELATION OF THE DIFFERENT FORMS OF *Toxoptera graminum.*

The stem mother, judging from the known life cycle of other aphids, appears in the spring and is the progeny of the male and the true female. There is a single generation each year and the generation consists entirely of stem mothers. The origin and relation of the apterous and winged agamic forms are the same as in other related species of aphids. Either one may be the progeny of the stem mother, the winged, or the apterous agamic forms, though comparatively few winged forms are produced by winged forms. The apterous individuals by far outnumber the individuals of all the other forms and are chiefly responsible for the large number of individuals which appear, and the great injury which is done to the growing grain. None of the other forms ever become numerous enough to do much harm. Winged migrants appear in large numbers at times, but this is usually not until the injury has been done. They take wing and drift to other fields, and serve to spread the species and to tide it over those seasons when food becomes scarce and it is necessary to seek food in other localities.

In order to determine the origin and relation of the other forms two series of experiments were performed, beginning early in October, 1908, about the time the first sex forms appeared. Preceding these series of experiments careful observations were made, once a week during June, July and August, to ascertain if any marked variations could be noted in the generations preceding the sexual generations, but no variations were noted in wingless forms and practicallynone in winged forms. Occasionally an individual with one branch of the third discoidals missing was found. Offspring of several of these were reared but they were found to be normal.

The object of the first series of experiments was to ascertain whether the parents of the intermediate forms, the true females and the males, were winged or wingless, or both. For this purpose I have selected several adults, either all winged or all wingless, and placed them on plants in breeding-cages. When they had produced a sufficient number of young he removed the adults and reared the young, and at maturity noted the number of individuals of each form represented in the first partial generation. From these he selected a convenient number, all winged or all wingless, and placed them on a plant to secure individuals of the second generation, and so on until the sexual forms ceased to appear.

The results of some of these experiments are tabulated in tables XXI to XXX, pages 121 *et seq.*

The data preserved were: The number of the generation given in the first column, the dates when the first and the last individuals of each partial generation were born, the dates when the first and the last individuals matured, the number of apterous agamic females, winged agamic females, winged intermediate females, males and true females in each generation, and the characteristics of the parents. The numbers in the columns under "Character of individuals," represent the number reared to maturity, in each case. In some cases the number reared to maturity was very small, owing to accidents or failure of food supply.

THE TRUE FEMALE.

The true female was first observed October 23, 1907. (See fig. 33.) In 1908 it appeared first October 3. A large number of experiments were at once started for the purpose of determining the number of eggs laid by a single individual, period of oviposition, and place of depositing the egg. The results of the experiments for 1907 were very unsatisfactory, because, owing to our failure to rear the true female, we were compelled to experiment with specimens taken from our stock, many of which had probably been adults for some time and had deposited eggs before the experiments began; and again, the true females are much more restless than the viviparous forms, and it was a difficult matter to keep them in confinement, and nearly all succeeded in escaping before the experiment was complete. In the fall of 1908, however, true females were reared and isolated to determine the number of eggs deposited, and in no case were more than two eggs definitely determined as oviposited by a single female. As shown by photographs, a larger number—six to twelve—were formed in the body.

From the many experiments carried on I have selected all those in which eggs were secured, and a few of those in which none were secured, and arranged the data in the table (pp. 119, 120). These experiments were carried on indoors, but the temperatures given are from Doctor Snow's weather report for Lawrence, Kan.

CONCLUSIONS.

No very definite conclusions can be drawn from this series of experiments; but we may say, on one hand, that the true female deposits more than one[1] egg, and, on the other, she deposits a very small number as compared with the number of young produced by the viviparous forms. The eggs were deposited, some on the blade of wheat and others on the sides of the breeding-cage.

1. On one blade of wheat in our stock I found a cluster of seven eggs, apparently the eggs of one individual.

EXPERIMENTS WITH TRUE FEMALES

DATE.	Temperature.			Number of experiment.													
	Max.	Min.	Mean.	1	2	3	4	5	6	7	8	9	10	11	12	13	18
1907.																	
Oct. 23	72	48	60.00	1f.	1f.	1f.	1f.	1f.	1f.	.....	.....	.....	.....	.....	.....	.....	.....
" 24	79	49	65.37	1	0	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....
" 25	57	44	48.75	0	0	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....
" 26	52	43	48.12	0	1	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....
" 27	52	40	43.50	0	0	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....
" 28	55	30	46.75	0	1	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....
" 29	49	45	46.75	0	0	0	1	0	0	.....	.....	.....	.....	.....	.....	.....	.....
" 30	55	45	50.75	0	0	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....
" 31	54	55	50.00	1	0	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....
Nov. 1	62	52	55.25	dis.	dis.	dis.	1	dis.	0	.....	.....	.....	.....	.....	.....	.....	.....
" 2	62	39	57.50	.....	.....	.....	dis.	.....	0	.....	.....	.....	.....	.....	.....	.....	.....
" 3	65	38	52.75	.....	.....	.....	.....	.....	0	.....	.....	.....	.....	.....	.....	.....	.....
" 4	64	41	52.50	.....	.....	.....	.....	.....	d.	.....	.....	.....	.....	.....	.....	.....	.....
" 5	62	42	52.75	.....	.....	.....	.....	.....	.....	1f.	1f.	1f.	.....	.....	.....	.....	.....
" 6	68	38	53.38	.....	.....	.....	.....	.....	.....	0	0	0	10f.	.....	.....	.....	.....
" 7	66	42	54.50	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	.....	.....
" 8	54	41	46.75	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	.....	.....
" 9	62	37	45.75	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	.....	.....
" 10	41	27	30.88	.....	.....	.....	.....	.....	.....	0	0	0	0	.....	.....	.....	.....
" 11	32	24	27.88	.....	.....	.....	.....	.....	.....	0	0	0	2	.....	.....	.....	.....
" 12	36	25	27.50	.....	.....	.....	.....	.....	.....	0	0	1	0	.....	.....	.....	.....
" 13	51	21	35.50	.....	.....	.....	.....	.....	.....	0	0	0	0	1f.	1f.	.....	.....
" 14	39	20	31.13	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....
" 15	46	25	35.80	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....
" 16	45	25	35.63	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....
" 17	54	27	39.38	.....	.....	.....	.....	.....	.....	0	0	0	0	0	0	.....	.....
" 18	54	29	43.00	.....	.....	.....	.....	.....	.....	0	0	0	2	0	0	.....	.....
" 19	52	35	43.75	.....	.....	.....	.....	.....	.....	0	dis.	0	2 dis. 0	0	2	1f.	.....
" 20	49	33	44.38	.....	.....	.....	.....	.....	.....	0	.....	0	0	0	0	1 dis.	.....
" 21	52	33	41.75	.....	.....	.....	.....	.....	.....	0	.....	dis.	0	0	0	.....	.....
" 22	49	30	36.00	.....	.....	.....	.....	.....	.....	[illegible]	.....	.....	3 dis. 2	0	dis.	.....	.....
" 23	52	27	41.75	.....	.....	.....	.....	.....	.....	dis.	.....	.....	2 d. 0	0	.....	.....	1f.
" 24	58	36	46.63	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0
" 25	60	38	49.13	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0
" 26	59	36	47.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0
" 27	58	41	46.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0
" 28	49	31	39.13	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0

EXPERIMENTS WITH TRUE FEMALES—CONCLUDED.

DATE.	Temperature.			Number of experiment.													
	Max.	Min.	Mean.	1	2	3	4	5	6	7	8	9	10	11	12	13	13
Nov. 29	50	30	41.88	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0
" 30	43	28	34.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 d.	0	.....	.....	0
Dec. 1	50	24	38.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	.....	.....	0
" 2	36	25	29.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	lost	.....	.....	0
" 3	40	24	30.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	.....	0
" 4	36	24	29.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....	.....	0
" 5	49	25	39.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 d.	.....	.....	.....	0
" 6	55	40	47.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	d.
" 7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Totals	.....	.....	.....	2	2	0	2	0	0	0	0	1	6	0	2	1	0

TABLE XXI. EXPERIMENT No. 2.

No. of generation.	Date of birth.		Date of maturity.		Character of individuals.					Character of parents.
	First.	Last.	First.	Last.	Apt. ag....	Wgd. ag...	Intermediate....	Male.....	Female...	
1	Sep. 9	Sep. 14	Sep. 14	Sep. 19	20	....	....	....	....	Normal winged migrant.
2	Sep. 14	Sep. 21	Sep. 25	Oct. 1	5	....	....	....	....	6 apterous agamic.
3	Sep. 29	Oct. 12	Oct. 9	Oct. 19	7	....	....	....	....	5 apterous agamic.
4	Oct. 9	Oct. 12	Oct. 19	Oct. 20	44	1	....	....	....	7 apterous agamic.
5	Oct. 19	Oct. 20	Nov. 3	Nov. 5	10	1	1	...	6	44 apterous agamic.

TABLE XXII. EXPERIMENT No. 3.

No. of generation.	Date of birth.		Date of maturity.		Character of individuals.					Character of parents.
	First.	Last.	First.	Last.	Apt. ag....	Wgd. ag..	Intermediate....	Male.....	Female...	
1	Sep. 21	Sep. 26	Sep. 26	Oct. 3	5	....	....	....	....	Winged migrant.
2	Sep. 26	Oct. 1	Oct. 6	Oct. 7	4	....	....	....	....	1 apterous agamic.
3	Oct. 9	Oct. 12	Oct. 19	Oct. 22	6	....	....	....	3	4 apterous agamic.

TABLE XXIII. EXPERIMENT No. 4.

No. of generation.	Date of birth.		Date of maturity.		Character of individual.					Parents and remarks.
	First.	Last.	First.	Last.	Wingless agamic..	Winged agamic..	Intermediate....	Male.....	Female...	
1	Sep. 17	Sep. 18	Sep. 23	Sep. 26	13	....	....	....	....	10 normal winged migrants.
2	Sep. 23	Sep. 26	.....	Oct. 6	26	....	....	....	....	13 apterous agamic.
3	Oct. 7	Oct. 8	Oct. 15	Oct. 17	20	1	....	....	....	26 apterous agamic.
4	Oct. 15	Oct. 16	Oct. 26	.....	11	....	....	....	6	20 apterous agamic.
5	Oct. 28	Dec. 5	Nov. 9	Dec. 14	15	1	4	....	6	1 apt. aga. entire gen'rat'n.
	" 28	Nov. 25	" 9	" 4	15	3	6	....	5	1 " " "
6	Nov. 19	Dec. 5	Dec. 10	Dec. 18	16	2	3	1	1	1 apt. aga. entire gen'rat'n.
	Dec. 3	" 12	" 16	" 23	7	1	1	2	....	1 " " partial gen'rat'n.

TABLE XXIV. EXPERIMENTS NOS. 9 AND 11.

No. of generation.	Date of birth. First.	Date of birth. Last.	Date of maturity. First.	Date of maturity. Last.	Character. Wingless agamic.	Winged agamic.	Intermediate.	Male.	True female.	Parents and remarks.
1	Sep. 18	Sep. 19	Sep. 24	Sep. 25	42	....	....	....	....	10 normal winged migrants.
2	Sep. 24	Sep. 28	Sep. 3	Sep. 7	69	....	....	....	....	42 apterous agamic.
3	Oct. 3	Oct. 7	Oct. 13	Oct. 14	85	3	....	....	....	85 apterous agamic.
4	Oct. 13	Oct. 15	Oct. 20	Oct. 22	57	4	....	....	14	apterous agamic.

TABLE XXV. EXPERIMENTS NOS. 14 AND 17.

No. of generation.	Date of birth. First.	Date of birth. Last.	Date of maturity. First.	Date of maturity. Last.	Character. Wingless agamic.	Winged agamic.	Intermediate.	Male.	True female.	Parents and remarks.
1	Oct. 15	Oct. 16	Oct. 22	Oct. 28	18	7	2	....	3	20 wingless agamic.
	" 16	" 17	" 28	" 31	10	1	1	1	4	
					28	8	3	1	7	

TABLE XXVI. EXPERIMENTS NOS. 13 AND 16.

No. of generation.	Date of birth. First.	Date of birth. Last.	Date of maturity. First.	Date of maturity. Last.	Character of individuals. Wingless agamic.	Winged agamic.	Intermediate.	Male.	True female.	Character of parents and remarks.
1	Oct. 15	Oct. 17	Oct. 22	Oct. 29	98	1	....	....	1	20 winged migrants.
2	Oct. 22	Oct. 24	Nov. 4	Nov. 5	37	2	....	....	....	70 wingless agamic.

TABLE XXVII. EXPERIMENTS NOS. 18 AND 19.

No. of generation.	Date of birth. First.	Date of birth. Last.	Date of maturity. First.	Date of maturity. Last.	Character of individuals. Apterous agamic.	Winged agamic.	Intermediate.	Male.	True female.	Character of parents and remarks.
1	Oct. 17	Oct. 22	Nov. 2	Nov. 6	36	10	3	....	3	15 winged migrants.

TABLE XXVIII. EXPERIMENT No. 27.

No. of generation.	Date of birth.		Date of maturity.		Character of individuals.					Character of parents.
	First.	Last.	First.	Last.	Wingless agamic.	Winged agamic.	Intermediate.	Male.	True female.	
1	Oct. 5	Oct. 6	Oct. 14	Oct. 16	8	....	....	2	2	5 apterous agamic females.
2	Oct. 16	Oct. 16	Oct. 30	Nov. 2	1	....	....	....	1	1 apterous agamic female.
3	.....	.....	.....	.....	....	....	....	....	....	.....

TABLE XXIX. EXPERIMENT No. 32.

No. of generation.	Date of birth.		Date of maturity.		Character of individuals.					Character of parents.
	First.	Last.	First.	Last.	Wingless agamic.	Winged agamic.	Intermediate.	Male.	True female.	
1	Oct. 8	Oct. 10	Oct. 16	Oct. 19	4	....	....	....	2	6 apterous adults.

TABLE XXX. EXPERIMENT No. 50.

No. of generation.	Date of birth.		Date of maturity.		Character of individuals.					Character of parents.
	First.	Last.	First.	Last.	Wingless agamic.	Winged agamic.	Intermediate.	Male.	True female.	
1	Oct. 31	Nov. 3	Nov. 11	Nov. 13	3	....	1	0	2	1 apterous adult.
2	Nov. 17	Nov. 28	Nov. 27	Dec. 16	14	....	....	....	....	1 apterous adult.

SUMMARY.

Number of partial generations reared from winged agamic parents..... 6

Number of offspring reared from winged agamic parents:

Apterous agamic females	209
Winged agamic females	10
Winged intermediate females	3
True females	4
Males	0
Total	226

Number of partial generations reared from apterous agamic parents... 21

Number of offspring reared from apterous agamic parents:

Apterous agamic females	487
Winged agamic females	27
Winged intermediate females	19
True females	55
Males	6
Total	594

It will be seen from the foregoing tables and summary that the parents of the intermediate forms and the true females may be either winged or wingless, but so far as the evidence goes the parents of the males are wingless. In experiments carried on a year ago, three males were reared, all of which were the offspring of wingless forms.

The second series of experiments was conducted for the purpose of ascertaining the character of the offspring of single individuals. For this purpose single individuals were selected and isolated on plants in breeding-cages. All the young of the generation were reared and the character of the adults noted. The most important of these experiments are tabulated in the following table:

TABLE XXXI. Complete generation of single individuals.

Character of parents.	Date of birth of offspring.		Date of maturity of offspring.		Character of offspring.					Number of experiment, and remarks.
	First.....	Last.....	First.....	Last.....	Wingless agamic..	Winged agamic..	Winged intermediate....	Male.....	True female..	
Wingless agamic..	Nov. 6	Dec. 11	Nov. 19	Dec. 19	34	....	.....	....	....	Exp. 22a.
Apt. ag. female..	Oct. 28	Dec. 5	Nov. 9	Dec. 14	15	1	4	....	6	Exp. 24a.
" ..	" 27	Nov. 9	" 11	Nov. 22	19	....	2	....	....	" 27a.
" ..	" 28	" 27	" 6	Dec. 14	33	2	9	....	3	" 29a.
" ..	" 24	" 22	" 6	" 4	14	1	14	....	13	" 30a.
" ..	" 28	" 25	" 7	" 7	49	5	.....	.....	....	" 33a.
" ..	" 28	" 25	" 7	" 4	15	3	6	....	5	" 31a.
" ..	Nov. 19	Dec. 5	Dec. 10	" 18	16	2	3	1	1	" 36a.
" ..	Dec. 3	" 12	" 16	" 23	7	1	1	2	....	" 37a.
Winged....	Nov. 4	" 12	Nov. 14	" 23	38	1	.....	.....	....	" 34. Adult, retained wing-pads throughout experiment. January 6 she was removed and mounted.
Winged....	Oct. 1	Oct. 6	Oct. 13	Oct. 16	6	....	.....	.....	....	Exp. 5. Adult, retained wing-pads throughout experim't. Died Oct. 10.
Winged....	Oct. 3	.....	Oct. 10	Oct. 20	23	....	.....	.....	....	Exp. 8.
Total.....	.....	.....	.....	.....	269	16	39	3	28	

It will be seen from the foregoing table that the apterous agamic females far outnumber all the other forms. In those generations which include sexual forms the apterous agamic individuals make up 58 per cent. of the number, the winged agamic individuals about 8 per cent., the winged intermediate about 19 per cent., the males about 1½ per cent., and the true females 13½ per cent. Of the sexual individuals reared only 10 per cent. were males. The number of sexual forms reared was too small to make the comparison as to relative numbers accurate.

The relative number of males this season, 1908, was much smaller

than last fall. Last fall we had no difficulty in finding males on our stock, but this fall only an occasional one could be found.

The experiments also show that the intermediate forms belong to the sexual generation, and are not transitional forms in the sense that they belong to a generation preceding the sexual generation, nor are they transitional in the sense that in the sexual generation they constitute the first individuals of the generation born. There seems to be no regular order as to the time when they appear in the generation.

They seem to be parthenogenetic individuals which are affected by the same causes that bring about the change from parthenogenetic females to sex forms, and their external characteristics are modified to a greater or less degree, but the reproductive organs are unmodified in some and only partially so in others.

They play no essential part in the life of the insect; the species could get along as well without them. While fully developed young or both young and winter eggs are visible in their bodies, not one was observed to give birth to its young or deposit its eggs. I have isolated many for the purpose of securing their young and eggs, but in no case did he succeed in getting young or eggs from them.

In about a week after maturity their bodies become very much distended, and they so remain until their death, which occurs about three weeks after maturity.

I have also observed many of the apterous agamic individuals, belonging to the sexual generation, which likewise were unable to give birth to their young. In fact, all the viviparous forms are much less prolific while the sexual forms are present than normal; the number of young produced being less than half of the average number.

VARIED OFFSPRING OF ONE INDIVIDUAL.

The unstability of the characteristics and the extremes to which variability extends at the time when the sexual forms are appearing may be noted by considering the many forms which one parent may give birth to. In experiment 36*a*, every form of which a record was kept was produced by a single apterous agamic female. Indeed, a single apterous individual may give birth to:

1. Apterous agamic females.
2. Winged agamic females.
3. Winged individuals resembling the winged agamic female in some characteristics and the true female in other characteristics, and producing only living young.

4. Winged individuals, resembling the winged agamic females in some characteristics and the true female in other characteristics, and producing both living young and winter eggs.

5. Apterous individuals resembling the true female in external characteristics and producing only living young.

6. Apterous individuals resembling the true female in external characteristics, and producing both living young and winter eggs.

7. True females, and

8. Males.

INSECT ENEMIES OF THE GREEN BUG.

PREDATORY.

Syrphus Flies.— Wherever colonies of plant-lice exist there will also very likely be found small, brightly barred, bee-like flies hovering about. Last season in the infested grain-fields these flies were sometimes so abundant in places as to make a humming noise like that of bees around the hive.

If these bee-like flies are watched, now and then one will alight and deposit a small, clear white egg in the immediate vicinity of the colony of plant-lice. These eggs soon hatch into yellowish-green footless grubs, to prey upon the surrounding aphids. Delicate in structure, harmonizing in color with their surroundings, these fly larvæ often escape notice. Their bodies taper headward, terminating in a pair of hooks. Without feet, they progress by extending the body forward as far as possible and, holding on by the hooks, draw the body forward. Established in the midst of a colony of plant-lice, one of these larvæ remains quiet until all aphids within reach are destroyed. It does not devour, but, grasping with its mouth, lifts the aphid from the surface and sucks its juices, then drops it, to take up another specimen to be held helpless, struggling in midair until its vitality is sapped.

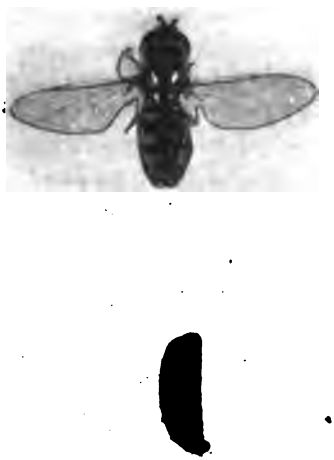


FIG. 36. Syrphus fly, *Syrphus arcuatus*, and pupa, enlarged. From photograph. (Original.)

When developed these larvæ draw up into an oblong mass and there form an apparently solid covering, underneath which first the true pupa and then the fly is formed (see figure 36).

These flies develop rather speedily; several broods appear within the year and each participates in reducing the number of injurious plant-lice.

The Aphis-lion.— In the summer-time in Kansas, flying some-

what irregularly in the midst of vegetation, are to be seen certain frail, gauzy-winged insects. And as they walk about, the lace-like fresh green wings, delicate body and eyes of shining gold give them a wonderfully beautiful appearance. Now the female of these insects deposits her eggs each on the tip of a tiny protecting stalk, and from these soon hatch the ferocious little aphis-lions. Extremely active and industrious in quest of plant-lice are these young aphis-lions. Each has a pair of long, pointed, slender jaws, grooved on the inner surface. The aphis-lion coming upon a plant-louse pierces the body with these sharp jaw-points and there the victim remains impaled until its blood has satisfied this bloodthirsty creature. These aphis-lions will also attack larger insects. They will also prey upon defenseless eggs of other insects. In fact, it is because of this, probably, that the female lace-winged fly places her own eggs upon stalks to prevent these tiny insects from preying upon the still unhatched eggs of their brothers and sisters. The development from the egg to maturity consumes about four weeks. Half of this is as an aphis-lion, and then half as a cocoon in a curled leaf or in some crevice in a plant stem, to emerge at the end of the period as the delicate green adult (see figs. 5 and 6).

The Ladybird Beetle.—From time to time during the wheat-growing season last year letters, accompanied by packages of slug-like larvæ similar to figure 5*b*, brought the complaint that these forms were unusally abundant and were causing serious damage to the grain. The wheat was not flourishing and the most conspicuous cause for this condition seemed, in the minds of these letter-writers, to be these larvæ or immature forms of the ladybird beetle. A continued observation would have shown that these larvæ were not feeding on the wheat but were devouring a great number of the less noticeable plant-lice, the presence of which on the wheat was really accountable for the sickly appearance of the grain. In all, there are about 150 species of these ladybird beetles known in the United States. Reddish-brown with black dots or black with reddish spots are the prevalent colors. A rather detailed account of the practical use made of one of these insects is given in another part of this report.

FIG. 37. *Coccinella abdominalis.* A ladybird which devours the "green bug." Greatly enlarged. (Original.)

The eggs of those which attack the wheat may be found in little

nents with
M NOVEMBER 2

37 47

groups of a dozen or so, attached to blades of grain. The larvæ—a full-grown one is shown in figure 5*b*—readily devours the plant-lice. For example, in a series of experiments we have found that they are capable of destroying numbers according to the following data:

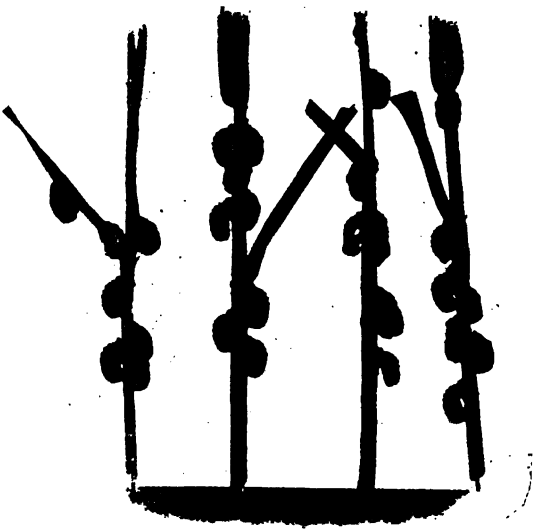


FIG. 38. Group of pupæ of ladybug, *Hippodamia convergens*, attached to wheat stalks. Natural size. From photograph. (Original.)

They do not confine themselves to plant-lice but they also feed voraciously on scale-insects. As noted elsewhere in this report, one was observed devouring the adult parasite of the green bug.

When full grown these larvæ attach themselves to leaves or stems and do not throw off their last outer covering. Figure 38 shows the tendency of these forms to congregate at times of pupation. Out of these forms come the adult beetles to repeat the cycle. Verily these are true insect friends of the farmer and fruit grower.

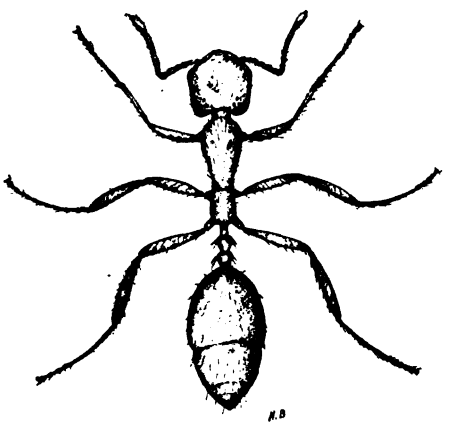


FIG. 39. *Monomorium minutum* Mayr, var. minimum Buckley. A small black ant observed carrying away "green bugs." Greatly enlarged. (Original.)

In four experiments with four different *Hippodamia convergens*, lasting for twenty-five days, in one experiment with *C. twelve-punctata*, continuing sixteen days, and ten experiments with as many *Chilocorus bivulnerus* for fifteen days, it was found that each of these various ladybird beetles would eat from fifty to sixty green bugs per day,

and on some days, incredible as it may seem, twelve of the sixteen individuals did devour 100 green bugs.

These experiments were carried on with adults which emerged from pupa brought into the laboratory. The beetles emerged in confinement and were kept in individual breeding-cages, where they could get nothing except what they were fed.

Only a definite number of green bugs were put in each breeding-cage. The ladybirds were fed once every twenty-four hours. The green bugs were eaten almost as soon as they were put in. The fact that there were no aphids left over from one day to the next shows the ladybird would have eaten more had she had the opportunity.

To determine how many green bugs one ladybird larva will eat, it was fed as follows:

April 13	38	green bugs.
" 15	10	" "
" 16	30	" "
" 18	45	" "
" 19	28	" "
" 20	28	" "
" 22, larva pupated.		
Total, 9 days	179	green bugs.

PARASITIC.

The wasp-like parasite (*Lysiphlebus Tritici*) is doubtless the greatest insect foe of the green bug. Experimental and observational data upon the behavior of the insect may be conveniently brought together in the following order:

1. Mode of development.
2. Number of eggs deposited by a single female.
3. Relative number of males and females.
4. Parthenogenesis.
5. Length of time required for growth and development in different seasons of the year.
6. Length of life of adult.
7. As a parasite on species of plant-lice other than green bugs.
8. Parasitization on immature green bugs.
9. Number emerging from one host.
10. Points in anatomy.
11. Original description.
12. Variations.
13. Summary.

EXPERIMENTS WITH *Lysiphlebus tritici.*

Experiments were carried on both in the field and laboratory for the purpose of determining the number of green bugs killed by a single female parasite; the time required for the development of the parasite at different temperatures; the relative number of male and female parasites; the length of life of the adult; whether or not the parasite breeds parthenogenetically, and, if so, the character of the offspring; whether or not the *Lysiphlebus tritici* will oviposit in other species of plant-lice, and whether or not the parasite will sting very young bugs, and, if so, whether the parasite will develop.

The experiments fall into two series: (1) Winter and spring; (2) summer.

The field experiments were carried on in breeding-cages consisting of a flower-pot and lamp-globe placed in a cheese-cloth covered tent. The temperature was taken from a self-recording thermometer placed in the tent. In the laboratory the same style of breeding-cages were used, but the tent was unnecessary. The temperature was taken from a self-recording thermometer placed on the table on which the breeding-cages were placed.

The data preserved, as well as the numbers of parasites and green bugs used in the different experiments, vary, making it difficult to tabulate the data satisfactorily; however, an attempt has been made to do so in the charts which follow.

The numbers at the top of the page in the tables are the report numbers of the experiment; next below the number of the experiment is the date on which the experiment began; below this are the abbreviations "Par." and "G. B." to denote the columns devoted to each. In case the number of males and females which emerged were counted, two columns are devoted to the parasite; the first to the male and the second to the female. Next comes the numbers in each column to denote the number of parasites and green bugs used in each experiment. The numbers to the left indicate the number of days after the date of beginning of the experiment. In the first experiment recorded (No. 5) the date is March 19. Hence the figure "1" at the left represents in this case March 20, "2" represents March 21, etc.; "d." or "dis." in the parasite column denotes that the parasite either "died" or "disappeared"; "e" in the parasite column stands for "emerged," the numbers following showing the number

which emerged on different days; "d" in the green bug column stands for "died" or dying, the numbers following indicating the number which died on different days. The "braces" indicate the period during which parasites were present, parasites were emerging, or green bugs dying.

In experiment No. 5 only an estimate is given of the parasites seen each day; no actual count was made. In experiment No. 11 accurate count of the number of dead bugs was not made each day. Estimates were made each day, and at the close of the experiment all of the dead bugs were accurately counted, so that the total number of dead bugs shown is correct, but the number which died each day was made up from the approximate estimates. In many of the experiments in which a large number of bugs were used, the plant usually died before the conclusion of the experiment, and many of the bugs either starved or else were lost in transferring to a new plant. For this reason the number of dead bugs is not so large as it would otherwise have been in these cases.

In making the summaries for the various charts only such data were included as were accurately recorded and sufficiently complete to be of use in working out the final conclusions. The tables are inserted between pages 128 and 129.

WINTER AND SPRING.

Experiments in the field began early in December, but the weather was too cold to make tangible results possible until March. No attempt has been made to tabulate the data of the field experiments during the winter months. Many experiments were started but they gave only negative results, because, while the parasites usually were observed to sting many of the bugs, the bugs were either killed by the cold or in seeking shelter escaped from the cages, so that the results of the work of the parasite could not be ascertained. An account of four experiments will serve to bring out the points of interest.

Experiment No. 1.—Three female parasites were placed in a cage with about twenty-five green bugs December 16. The green bugs and parasites were reared in the laboratory. They were removed to the field about one o'clock in the afternoon. The temperature in the laboratory at that time was 65°F., and in the field 45° F. The parasites were not very active but were observed to sting bugs. From December 17 to 19 the temperature was below freezing all the time. The parasites remained motionless on the blades until the 19th, when they were found dead on the ground. The green bugs gradually disappeared. January 24 two bugs died,

apparently on account of the cold weather. If they died as the result of the sting of the parasite, the parasite within also died, for later the bugs shriveled, and no parasites emerged from them.

Experiment No. 2.—This experiment is of interest because it shows how low a temperature the adult parasite can endure. December 19, at 1 o'clock P. M., I placed four female parasites, reared in the laboratory, with twelve green bugs. The temperature at the time was 35° F. The parasites moved about slowly and tried in a feeble way to sting the green bugs.

December 20, at 9:30 A. M., the temperature was 28½° F. One parasite was dead, and the others were crawling about slowly on the ground. It required about a minute for one to crawl three-fourths of an inch. At 2:30 P. M., the temperature was 51° F. The parasites were still alive and one was observed stinging a bug. Maximum temperature for 20th, 51° F.; minimum, 21° F.; mean, 30.12°.

December 21, 9 A. M. I saw but one parasite; it was motionless on the ground. Maximum temperature for 21st, 36° F; minimum, 17° F.; mean, 25.83°.

December 23, 9 A. M. All three parasites were on the glass; two alive, one dead. Maximum temperature for 22d, 32° F.; minimum, 30° F.; mean, 31.04°. Maximum temperature for 23d, 37° F.; minimum, 24° F.; mean, 38.33°.

December 24, 9:30 A. M. The parasites were motionless on the glass; temperature, 30° F. Maximum for 24th, 51° F.; minimum, 23° F.; mean, 33.91°.

December 26. One parasite was seen alive. Maximum for 25th, 49° F.; minimum, 27° F.; mean, 34.54°. Maximum for 26th, 57° F.; minimum, 26° F.; mean, 37.20°.

December 27. One parasite was found dead. I could not find the other one. Maximum for 27th, 61° F.; minimum, 31° F.; mean, 44.26°.

It will be seen from this experiment that the adult parasite can endure a considerable amount of cold weather, and become active in the warmer part of the day.

Whether they were successful in their attemps to oviposit in the green bugs or not could not be ascertained, because the green bugs either died from the effects of the cold or escaped before the parasites developed.

Experiment No. 3.—December 20. I transferred a pot of wheat plants containing about fifty parasitized bugs from the laboratory

to the field, and observed the number of parasites which emerged. They emerged as follows:

TABLE XXXIV.

DATE.	Par.	Temperature.			DATE.	Par.	Temperature.		
		Max.	Min.	Mean.			Max.	Min.	Mean.
Dec. 21..	0	36°	17°	25.83°	Jan. 14..	0	74°	16°	38.54°
" 22..	-	32	30	31.04	" 15..	2	37	11	28.36
" 23..	0	37	24	38.33	" 16..	0	39	7	18.41
" 24..	0	51	23	33.91	" 17..	0	53	17	30.04
" 25..	0	49	27	34.54	" 18..	*1	59	16	31.67
" 26..	0	57	26	37.20	" 19..	-	58	19	35.62
" 27..	-	61	31	44.26	" 20..	1	65	34	41.41
" 28..	1	64	21	30.81	" 21..	0	67	31	47.83
" 29..	-	54	31	38.25	" 22..	0	44	23	32.54
" 30..	0	45	20	31.75	" 23..	0	37	8	14.29
" 31..	-	52	20	34.75	" 24..	0	43	7	22.12
Jan. 1..	-	56	23	34.29	" 25..	0	60	19	34 50
" 2..	3	55	21	32.50	" 26..	-	69	21	38.54
" 3..	-	40	27	35.33	" 27..	1	53	14	31.83
" 4..	1	58	28	38.26	" 28..	1	43	17	30 79
" 5..	-	58	20	31.45	" 29..	0	36	4	17.95
" 6..	5	54	24	37.16	" 30..	0	33	14	23.33
" 7..	-	54	22	36.83	" 31..	0	31	7	29.70
" 8..	0	51	24	36.20	Feb. 1..	0	23	-1	8 00
" 9..	0	59	24	37.93	" 2..	-	44	0	14.83
" 10..	0	75	27	41.16	" 3..	0	48	18	29.62
" 11..	-	36	23	27.83	" 4..	0	42	27	38.26
" 12..	-	47	20	30.91	" 5..	0	52	26	49.16
" 13..	4	78	21	32.00	" 6..	1	51	17	30 20

*Dead.

Mean temperature for period, 34.4°.
Total number of parasites emerged, 21.

Experiment No. 4.—Twenty-four green bugs which had been exposed to parasitic attack and two parasites were placed in the field December 30. The two parasites died January 2. The bugs died as follows:

Dec. 31.....	2	Jan. 11.....	1	Jan 21.....	1
Jan. 6.....	3	" 13.....	1	" 23.....	1
" 8.....	3	" 16.....	1	" 24.....	1
" 9.....	3	" 20.....	1	Mar. 7.....	1

Parasites emerged as follows: March 10, 1; March 12, 1.

March 4 mold appeared on the plant and dead bugs in the cage. The experiment was continued till March 28, but the two parasites noted above were the only ones to emerge.

The bug that died March 7 was parasitized in the field by the parasites placed with the bugs, or else in the laboratory just before being transferred to the field, hence the minimum period required for the development of the larvæ of the parasite was about 68 days.

Those that emerged on March 10 and 12 emerged in a minimum of 46 or 48 days—a maximum of 70 or 72 days after the death of the green bug. Adding these, we have as the maximum period of development of the parasite 140 days, and the minimum period 114 days, at a mean temperature of about 35°.

SUMMARY FROM ALL TABLES ON PARASITES.

From the foregoing summaries we get the following:

Maximum number of green bugs killed by a single parasite	95
Average number of green bugs killed by a single parasite	38.4
Per cent. of male parasites	34.5
Per cent. of female parasites	65.5
Average development period of parasite	17.66 days.
Average length of life of parasite	4.99 "
Average mean temperature	61.90°

The Number of Bugs Killed by a Single Female.

The average number of green bugs killed by a single parasite under natural conditions is probably much larger than the above figures show. When a large number of green bugs were used to begin with, the plant usually died before the experiment was complete, so many of the bugs which would have developed parasites were prevented from doing so by starvation, or else were lost in transferring from one plant to another. In some of the experiments only a small number of bugs were used, and in these cases if the parasite only lived two or three days, there were not enough green bugs to test fairly the power of the parasite. In some of the experiments the number of dead bugs was not counted. In these cases the number of dead bugs was determined from the number of parasites which emerged.

Relation of Temperature to Development Period.

The development period varied greatly, the minimum being 7 days, the maximum 37 days, and the mean, 17.66 days.

Summarizing the experiments according to the mean temperatures which prevailed during their progress, we have the following, table XXXVII:

Number of exp. performed.	Range of mean temp.	Development period.
1	35°	114–140 days.
17	55°—59 5°	23.4 "
18	60°—65°	16.06 "
22	65°—70°	13.7 "
3	70°—72.4°	11. "

Relative Number of Males and Females.

While in the individual experiments the relative number of

males and females varied greatly, in the three series of experiments with fertilized females tabulated the variations were slight, the maximum per cent. of females being 67, the minimum 64.5, and the average 65.5.

Two other counts were made to determine the relative number of males and females, as follows:

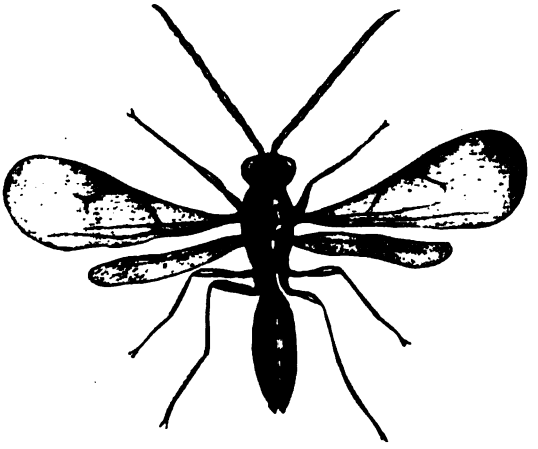


FIG. 40. *Lysiphlebus tritici*, male. The wasp-like parasite of the "green bug." Greatly enlarged. From photograph. (Original.)

Chesky, in May, 1907, took at random 1000 parasites out of about 5000 or 6000 that emerged, and counted the number of males and females. He used two different distinguishing characteristics:

(1) Male has blunt abdomen with claspers; female has sharp, pointed abdomen with ovipositor. (2) Male has never less than fourteen joints in the antennæ. Female has never more than thirteen. The following result was obtained: Males, 42; females, 958; total, 1000. One male to every $22\frac{3}{4}\frac{1}{2}$ females; per cent. of females, 95.8.

The parasites for this count were taken from the window of the room used for packing parasites for shipping. The large percentage of female parasites is remarkable.

Another count was made by Miss McDaniels. She placed parasatized bugs in tubes and removed and counted each day those which emerged. In this experiment, out of 945 parasites which emerged 329 were males and 616 were females. Percentage of females, 65.

In the parthenogenetic experiments the parasites which emerged were nearly all males. In twenty of the twenty-four experiments they were all males. In the other four there were only 7, making in the whole series, in which 402 parasites were reared, an average of 1.7 per cent. females.

Parthenogenesis.

The twenty-four experiments (Nos. 11, 12, 13, table XXX, and Nos. 48–68, table XXXIII), prove conclusively that the parasite is

parthenogenetic, and that the unfertilized females deposit fully as many eggs as do the fertilized females. Table XXXIII tends to show that the average number of dead bugs killed by a single parasite is less in the parthenogenetic experiments than in the others, but the reasons for this have been explained above. In experiment No. 11 the number of bugs killed was 95; in experiment No. 48 the number was 71. The former number was not exceeded in any of the experiments with fertilized females, and the latter was exceeded in only two cases.

FIG. 41. *Lysiphlebus tritici*, female. Greatly enlarged. From photograph. (Original.)

From the fact that only 1.7 per cent. of the offspring are females it is clear that the parasite could not multiply by parthenogenetic reproduction, since the average number of females produced by a single parthenogenetic female is a little less than 0.3.

Parthenogenetic production will occur in nature when the host aphids become very scarce, in which case, on account of the shortness of the life of the adult and the scattered condition of the males and females, many of the females fail to mate with the male.

In experiment No. 14 several parasites were placed with ten young, only one day old. The parsites were removed at the close of the first day. The green bugs all grew to maturity, were all viviparous wingless females, and nine died after the last moult *without producing any young*. Three parasites emerged.

In experiment No. 15 several parasites were placed with nineteen green bugs one day old, and remained to the end of the second day. The green bugs all grew to maturity and were all wingless; seventeen died *without producing any young*, and fourteen parasites emerged.

In experiment No. 17 one parasite was placed with about 200 green bugs from one to three days old. The parasite lived for six days, so that when the parasite died the bugs were from seven to nine days old. Many of the bugs died before maturing. Among the dead bugs were four with wings. In one case the bug died be-

fore the wings were fully spread. From these experiments we may conclude that the parasite does sting very young bugs; that when the temperature is such that the development of the parasite is slow, the green bug will develop and also the parasite within.

In experiments performed with the special purpose in view of ascertaining whether bugs, when stung in the immature stages, will develop into adults or not, the following results were obtained:

In two experiments adults were placed on a plant and left there over night. The next morning the adults were removed, leaving thirty young bugs in one case and forty-two in the other. Parasites were introduced, the bugs not having moulted the first time. After a few hours the parasites were removed. In the first cage thirteen parasitized bugs died before casting the fourth moult, and in the second cage thirty-three died after casting the third moult; one of which had wing-pads.

In three experiments, in which fifty-six bugs were used, the parasites were introduced before the bugs moulted the second time. Of this number thirty-eight died after casting the third moult. None developed wing-pads.

In another experiment parasites were introduced for a short time with forty bugs which had cast their second moult but not the third moult. Of this number eleven were parasitized, one dying before casting the fourth moult. The others cast the fourth moult but did not produce any young.

None of the parasitized bugs in the experiments performed developed wings, and only one had wing-pads. The number of those which escaped the parasites, and hence lived to be adults, was not recorded, but no winged forms were noted among them, and in our stock of bugs winged forms were very scarce.

We may conclude from these experiments that when bugs are stung before the first and second moults they will develop and cast the third moult before dying; if stung before the third moult they will mature before dying but will not give birth to young. Further experiments developed the fact that bugs kept in the laboratory stung after the fourth moult will give birth to from two to six young before dying. They cease to produce young two days before their death.

These experiments were performed when the mean temperature was about seventy-five degrees.

Will more than one parasite emerge from a single parasitized green bug?

In order to determine whether more than one parasite emerges from a single parasitized bug, 170 parasitized green bugs were taken

and enclosed in individual vials May 15. Between May 15 and May 30, 150 parasites emerged, and in each case there was but a single parasite per vial. The 20 parasitized bugs which failed to produce parasites were examined May 30 and no life was found to be present.

From the foregoing experiments it seems evident that more than one parasite does not develop from the body of the parasitized green bug.

Fastening the Parasitized Bug to the Blade.

Soon after the parasitized green bug dies, the larva of the parasite reaches maturity and begins to prepare to pupate. As it pupates within the skin of the parasitized bug its first step is to fasten the parasitized bug securely to the blade. In doing this it first cuts a median longitudinal slit in the ventral wall of the green bug (fig. 42).

FIG. 42. Ventral view of a parasitized "green bug," showing the longitudinal slit cut by the parasite, preparatory to fastening the bug to the blade of wheat.

The body of the larva at this time almost completely fills the shell of the green bug, so that in moving about in the shell the pressure exerted on the sides of the shell causes this slitto gape open as seen in the figure. The larva now thrusts its head and fore part of the body through the opening and fastens a web to the blade, and then, elevating its head, fastens it to the edge of the slit cut in the body of the bug. This operation is repeated until the parasite has completed the circuit; then it strengthens the attachment by weaving several layers of web inside. This web is at first mucilaginous, and the fine strands stick together, forming a perfect membrane, which soon hardens, giving it firmness, thus making the attachment strong and impervious to the elements.

a *b*

FIG. 43. (*a*) Parasitized "green bug." From photograph, greatly enlarged. (Original.) (*b*) Shell of "green bug" from which the parasite has emerged, showing the opening through which the adult parasite emerged. From a drawing. (Original.)

EXPERIMENTS TO DETERMINE PARTHENOGENESIS IN *Lysiphlebus tritici* AND CHARACTER OF OFFSPRING.

Preliminary to the work of each experiment, from No. 10 to No. 15 parasitized green bugs were isolated, each in a separate vial, stoppered by binding a double layer of extra close cheese-cloth.

The isolated dead green bugs were observed daily, and when the female parasites began to emerge (the males usually emerge first) one unfertilized female was selected for introduction into the lot of unparasitized green bugs. The stock from which the green bugs were taken was continued and served as a check upon the experimental material. The experiments were conducted by Professor Glenn and Miss McDaniels independently and are uniform in their results.

Experiment No. 49.—*February 13 to March 16, 1908.*

February 12, a single parasitized green bug placed in a vial.

February 13, female parasite emerged and was put in a breeding-cage with thirty green bugs which were free from parasites.

February 14, parasite active till March 5, when found dead.

February 27, several green bugs turning yellow.

March 4, 14 dead green bugs.

March 5, 12 dead green bugs.

March 9, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint as long as thick.

March 10, 6 parasites emerged—6 males; 6 males, 15-jointed antennæ, last joint as long as thick.

March 11, 6 parasites emerged—5 males, 1 female; 5 males, 15-jointed antennæ, last joint as long as thick; 1 female, 12-jointed antennæ, last joint 4 times as long as thick.

March 12, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint as long as thick.

March 16, 10 parasites emerged—10 males; 10 males, 15-jointed antennæ, last joint as long as thick.

Thirty green bugs were put in with one unfertilized female parasite. Twenty-six bugs were parasitized. Twenty-five male parasites emerged and one female. Experiment was carried on in a room where neither parasites nor green bugs had been bred.

Experiment No. 50.—*February 14 to March 16, 1908.*

Single parasitized green bug placed in a vial.

February 14, female parasite emerged and was placed in a breeding-cage with 30 green bugs which were unparasitized.

February 15, parasite active till February 25, when found dead.

February 20, green bugs turning yellow.

February 24, 10 green bugs dead.

February 25, 14 green bugs dead.

March 2, 6 green bugs dead.

March 4, 4 parasites emerged—3 females, 1 male; 1 male, 15-jointed an-

tennæ, last joint as long as thick; 3 females, 12-jointed antennæ, last joint 3 times as long as thick.

March 6, 12 parasites emerged—12 males; 12 males, 15-jointed antennæ, last joint as long as thick.

March 7, 1 parasite emerged—1 male; 1 male, 15-jointed antennæ, last joint as long as thick.

March 9, 6 parasites emerged—6 males; 6 males, 15-jointed antennæ, last joint as long as thick.

March 10, 2 parasites emerged—1 male, 1 female; 1 male, 15-jointed antennæ, last joint as long as thick.

March 11, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint as long as thick.

March 12, no parasites emerged.

March 16, no parasites emerged.

Thirty green bugs were used in the experiment, and thirty were parasitized. Twenty-seven parasites emerged; of these four were females with 12-jointed antennæ and twenty-three were males with 15-jointed antennæ. No life was present in the remaining shells.

Experiment No. 61.—*March 23 to April 11, 1908.*

A single parasitized green bug placed in a vial.

March 23, female parasite emerged and was placed in a breeding-cage with 20 unparasitized green bugs.

March 25, parasite dead.

March 30, green bugs turning yellow.

April 4, 10 green bugs dead.

April 5, 5 green bugs dead.

April 8, 1 parasite emerged—1 female; 1 female, 12-jointed antennæ; last joint 2 times as long as thick.

April 10, 10 parasites emerged—10 males; 10 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 11, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ; last joint 2 times as long as thick.

Twenty green bugs used; fifteen green bugs parasitized. Twelve parasites emerged—eleven males and one female. The female had 12-jointed antennæ, and the eleven males 14-jointed.

Experiment No. 51.—*March 17 to April 10, 1908.*

A single parasitized bug placed in a vial.

March 17, female emerged and was placed in a breeding-cage with 20 green bugs which were free from parasites.

March 18, parasite active.

March 19, parasite active.

March 20, parasite dead.

March 25, number of green bugs turning yellow.

March 27, 3 dead green bugs.

March 30, 14 dead green bugs.

April 2, 2 parasites emerged—2 males; 1 male, 15-jointed antennæ, last joint as long as thick; 1 male, 15-jointed antennæ, last joint 2 times as long as thick.

April 4, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2½ times as long as thick.

April 6, 7 parasites emerged—6 males, 1 female; 2 males, 15-jointed antennæ, last joint as long as thick; 4 males, 14-jointed antennæ, last joint 2 times as long as thick; 1 female, 13-jointed antennæ, last joint 2½ times as long as thick.

April 7, 2 parasites emerged—2 males; 2 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 8, no parasites emerged.

April 9, 1 parasite emerged—1 female; 1 female, 13-jointed antennæ, last joint 2½ times as long as thick.

April 10, 4 parasites emerged—3 males, 1 female; 1 female, 13-jointed antennæ, last joint 2½ times as long as thick; 3 males, 14-jointed antennæ, last joint 2 times as long as thick.

Twenty green bugs were used, and one infertile parasite. Seventeen parasites emerged, of which fourteen were males and three females. Four of the males had 15-jointed antennæ, the three females had 13-jointed antennæ, and the ten remaining males had 14-jointed antennæ.

Experiment No. 52.—*March 18 to April 9, 1908.*

March 17, a single parasitized green bug placed in a vial.

March 18, female parasite emerged and was placed in a breeding-cage with 20 green bugs which were free from parasites.

March 19, parasite active.

March 20, parasite dead.

March 25, green bugs turning yellow.

March 27, 7 dead bugs.

March 30, 11 dead bugs.

April 2, 9 parasites emerged—9 males; 3 males, 15-jointed antennæ, last joint as long as thick; 6 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 3, 5 parasites emerged—5 males; 5 males, 15-jointed antennæ, last joint 2 times as long as thick.

April 9, no parasites emerged.

The remaining skins were shriveled. No life present. Twenty green bugs were put in; eighteen were parasitized and fourteen parasites emerged. All parasites were males. Eight males had 15-jointed antennæ and six had 14-jointed antennæ.

Experiment No. 53.—*March 18 to April 9, 1908.*

A single parasitized green bug placed in a vial.

March 18, a female parasite emerged, and was placed with 20 unparasitized green bugs in a test-tube and taken to a room where neither green bugs nor parasites were put in store. The end of the test-tube was covered with cloth so that none of the bugs could escape nor others get in. The green bugs were fed from time to time.

March 21, parasite dead.

March 25, several green bugs turning yellow.

March 27, 12 dead green bugs.

March 30, 8 dead green bugs.

April 4, 3 parasites emerged—3 males; 3 males, 15-jointed antennæ, last joint 1½ times as long as thick.

April 6, 4 parasites emerged—4 males; 3 males, 15-jointed antennæ, last joint 1½ times as long as thick; 1 male, 14-jointed antennæ, last joint two times as long as thick.

April 7, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint 1½ times as long as thick.

April 9, 1 parasite emerged—1 male; 1 male, 15-jointed antennæ, last joint 1½ times as long as thick.

Twenty green bugs were used and twenty bugs were parasitized. Only ten parasites emerged, all of which were males. Nine males had 15-jointed antennæ and one 14-jointed antennæ.

Experiment No. 54.—*March 18 to April 9, 1908.*

Single parasitized green bug placed in a vial.

March 18, female parasite emerged and was placed in a breeding-cage with 30 unparasitized green bugs.

March 20, parasite dead.

March 25, a number of green bugs turning yellow.

March 27, 10 dead green bugs.

March 30, 14 dead green bugs.

April 1, 4 dead green bugs.

April 6, 6 parasites emerged—6 males; 3 males, 15-jointed antennæ, last joint 1½ times as long as thick; 3 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 7, 10 parasites emerged—10 males; 6 males, 15-jointed antennæ, last joint 1½ times as long as thick; 4 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 9, 10 parasites emerged—10 males; 5 males, 14-jointed antennæ, last joint 2 times as long as thick; 5 males, 15-jointed antennæ, last joint 1½ times as long as thick.

Thirty green bugs were used. Twenty-eight were parasitized. Twenty-six parasites emerged. All parasites that emerged were males. Fourteen of these had 15-jointed antennæ, and twelve had 14-jointed antennæ.

Experiment No. 55.—*March 18 to April 9, 1908.*

Single parasitized green bug placed in a vial.

March 18, female parasite emerged and was placed in a breeding-cage with 20 unparasitized green bugs.

March 23, parasite dead.

March 27, several green bugs turned yellow.

March 30, 4 dead green bugs.

April 1, 10 dead green bugs.

April 2, 12 dead green bugs.

April 4, 2 parasites emerged—1 male and 1 female; 1 male, 14-jointed antennæ, last joint 3 times as long as thick; 1 female, 12-jointed antennæ, last joint 3 times as long as thick.

April 6, 1 parasite emerged—1 male; 1 male, 15-jointed antennæ, last joint 1½ times as long as thick.

April 7, 9 parasites emerged—9 males; 9 males, 15-jointed antennæ, last joint 2 times as long as thick.

April 8, 10 parasites emerged—10 males; 4 males, 15-jointed antennæ,

last joint 1½ times as long as thick; 6 males, 14-jointed antennæ, last joint 2 times as long as thick.

Twenty green bugs were used; twenty-six green bugs parasitized. The six extras were offspring of the original twenty. Twenty-two parasites emerged, of which one was a female with 12-jointed antennæ, and twenty-one males, of which sixteen had 14-jointed antennæ and five 15-jointed antennæ.

Experiment No. 56.—*March 19 to April 8, 1908.*

Single parasitized green bug placed in vial.

March 19, female parasite emerged and was placed in breeding-cage with 20 green bugs two days old. See if green bugs will mature.

March 20, parasite active.

March 21, parasite active.

March 22, parasite active.

March 23, parasite active.

March 24, parasite dead.

March 25, several green bugs turning yellow.

March 27, the bugs have matured in a few instances; 6 young present, a number of adults dead.

March 28, no change till April 4.

April 4, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint 1½ times as long as thick.

April 6, 8 parasites emerged—8 males; 2 males, 15-jointed antennæ, last joint 2 times as long as thick; 1 male, 15-jointed antennæ, last joint as long as thick; 1 male, 15-jointed antennæ, last joint ½ as long as thick; 3 males, 15-jointed antennæ, last joint 3 times as long as thick; 1 male, 15-jointed antennæ, last joint 2 times as long as thick.

April 7, 8 parasites emerged—8 males; 1 male, 14-jointed antennæ, last joint as long as thick; 1 male, 14-jointed antennæ, last joint 2 times as long as thick; 1 male, 15-jointed antennæ, last joint 4 times as long as thick.

April 8, 2 parasites emerged—two males; 1 male, 14-jointed antennæ, last joint 1½ times as long as thick; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

Twenty green bugs were used and twenty were parasitized. Only fifteen parasites emerged, and all were males, of which eight had 14-jointed antennæ and seven 15-jointed. The remaining shells were shriveled up. All the green bugs had moulted at least three times, and six of them had completed the fifth moult and given birth to one young before death. Those which reached maturity were perhaps the last to be parasitized.

Experiment No. 57.—*March 19 to April 9, 1908.*

A single parasitized green bug placed in a vial.

March 19, female parasite emerged and was placed in a breeding-cage with 20 green bugs which were free from parasites.

March 20, parasite active.

March 21, parasite dead.

March 25, green bugs turning yellow.

March 27, 1 dead.

March 30, 13 dead.

THE PARASITE, *Lysiphlebus tritici*, AND ITS HOST, THE GREEN BUG.

FIG. 1. Male.

FIG. 2. Female.

FIG. 3. Larva.

FIG. 4. Female ovipositing on host.

FIG. 5. Parasitized "green bug" in early stages of parasitism.

FIG. 6. Shell of "green bug" from which parasite has emerged.

PLATE III

1

2

3

4

5

6

SIBYL BETTS

A. HOEN & CO., BALTIMORE

April 2, 3 parasites emerged—three males; 3 males, 15-jointed antennæ, last joint as long as thick.

April 3, 1 parasite emerged—1 male; 1 male, 15-jointed antennæ, last joint as long as thick.

April 4, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2½ times as long as thick.

April 6, 3 parasites emerged—3 males; 3 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 7, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

April 8, 3 parasites emerged—3 males; 3 males, 14-jointed antennæ, last joint 2 times as long as thick.

Twenty green bugs were used. Fourteen bugs were parasitized: twelve parasites emerged; all males. Four had 15-jointed antennæ and eight had 14-jointed antennæ.

Experiment No. 58.—*March 20 to April 9, 1908.*

A single parasitized green bug placed in a vial.

March 20, female parasite emerged and was placed in a breeding-cage with 20 unparasitized green bugs.

March 25, parasite dead.

March 27, green bugs turning yellow.

March 30, 4 green bugs dead.

April 1, 10 green bugs dead.

April 2, 4 green bugs dead.

April 3, 1 green bug dead.

April 6, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

April 7, 10 parasites emerged—10 males; 10 males, 14-jointed antennæ, last joint two times as long as thick.

April 8, 4 parasites emerged—4 males; 3 males, 14-jointed antennæ, last joint 2 times as long as thick; 1 male, 15-jointed antennæ, last joint as long as thick.

April 9, 2 parasites emerged—1 male, 1 female; 1 female, 13-jointed antennæ, last joint 2½ times as long as thick; 1 male, 15-jointed antennæ, last joint as long as thick.

April 10, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

Twenty green bugs were used in the experiment. Nineteen bugs were parasitized and eighteen parasites emerged. Of the parasites there were seventeen males and one female. The female had 13-jointed antennæ, and two males had 15-jointed antennæ.

Experiment No. 59.—*March 21 to April 7, 1908.*

A single parasitized green bug placed in a vial.

March 21, female parasite emerged and was placed with 10 green bugs which were free from parasites.

March 24, parasite dead.

March 30, green bugs turning yellow.

April 2, 7 green bugs dead.

April 3, 3 green bugs dead.

April 7, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, las joint 2 times as long as thick.

April 8, 2 parasites emerged—2 males; 2 males, 14-jointed antennæ, last joint 2 times as long as thick.

The remaining shells were shriveled up—no life present. Out of ten green bugs used ten were parasitized, but only three parasites emerged, and all these were males, with 14-jointed antennæ.

Experiment No. 60.—*March 23 to April 9, 1908.*

A single parasitized green bug placed in a vial.

March 23, female parasite emerged and was placed in a breeding-cage with 15 green bugs free from parasites.

March 25, parasite dead.

March 28, green bugs turning yellow.

March 30, 4 green bugs dead.

April 2, 10 green bugs dead.

April 7, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint 1½ times as long as thick.

April 8, 5 parasites emerged—5 males; 2 males, 15-jointed antennæ, last joint 2 times as long as thick; 3 males, 16-jointed antennæ, last joint as long as thick.

April 9, 1 parasite emerged—1 male; 1 male, 16-jointed antennæ, last joint as long as thick.

Fifteen green bugs were used. Fourteen were parasitized, and eight parasites emerged. All were males. Four males had 15-jointed antennæ and four had 16-jointed antennæ.

Experiment No. 62.—*March 24 to April 9, 1908.*

A single parasitized green bug placed in a vial.

March 24, female parasite emerged and was placed in a test-tube with 20 unparasitized green bugs. The end of the test-tube was closed with a piece of cloth so that bugs could not get out nor in. The green bugs were fed from day to day.

March 26, parasite dead.

March 30, green bugs turning yellow.

April 1, 4 green bugs dead.

April 2, 16 green bugs dead.

April 3, 5 green bugs dead.

April 7, 1 parasite emerged—1 male; 1 male, 15-jointed antennæ, last joint 2 times as long as thick.

April 8, 8 parasites emerged—8 males; 4 males, 14-jointed antennæ, last joint 2 times as long as thick; 4 males, 15-jointed antennæ, last joint 1½ times as long as thick.

April 9, 6 parasites emerged—6 males; 5 males, 15-jointed antenna, last joint as long as thick; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

April 10, 6 parasites emerged—6 males; 1 male, 15-jointed antennæ, last joint 2 times as long as thick; 5 males, 14-jointed antennæ, last joint as long as thick.

Twenty green bugs were used. Twenty-one (ncluding one offspring) bugs were parasitized. Twenty-one parasites emerged. All parasites were

males. Eleven had 15-jointed antennæ and ten had 14-jointed antennæ. This experiment was carried on away from the laboratory in a room where the temperature was kept up to seventy degrees the entire time, and for this reason the development took place more rapidly.

Experiment No. 63.—*March 28 to April 17, 1908.*

A single parasitized green bug placed in a vial.

March 28, female parasite emerged and was placed in a breeding-cage with 25 unparasitized green bugs.

April 1, parasite dead.

April 2, number of green bugs turning yellow.

April 4, 10 green bugs dead.

April 5, 7 green bugs dead.

April 6, 7 green bugs dead.

April 11, 2 parasites emerged—2 males; 1 male, 15-jointed antennæ, last joint 2 times as long as thick; 1 male, 15-jointed antennæ, last joint 1½ times as long as thick.

April 13, 12 parasites emerged—12 males; 4 males, 15-jointed antennæ, last joint as long as thick; 6 males, 15-jointed antennæ, last joint 2 times as long as thick; 2 males, 15-jointed antennæ, last joint 1½ times as long as thick.

April 14, 5 parasites emerged—5 males; 1 male, 15-jointed antennæ, last joint 2 times as long as thick; 3 males, 15-jointed antennæ, last joint as long as thick; 1 male, 15-jointed antennæ, last joint one-half as long as thick.

April 15, 2 parasites emerged—2 males; 1 male, 15-jointed antennæ, last joint as long as thick; 1 male, 15-jointed antennæ, last joint one-half as long as thick.

April 16, 1 parasite emerged—1 male; 1 male, 15-jointed antennæ, last joint 2 times as long as thick.

April 17, no parasites emerged.

Twenty-five green bugs were used. Twenty-four were parasitized and twenty-two parasites emerged. All were males. All had 15-jointed antennæ, although there was some variation in the length of the last segment of the antennæ.

Experiment No. 64.—*March 28 to April 18, 1908.*

A single parasitized green bug placed in a vial.

March 28, female parasite emerged and was placed in a breeding-cage with 10 unparasitized green bugs.

March 30, parasite dead.

April 3, green bugs turning yellow.

April 5, 2 green bugs dead.

April 6, 4 green bugs dead.

April 13, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

April 14, 1 male parasite emerged—14-jointed antennæ.

April 15, parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

April 16, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

April 17, 1 parasite, male, emerged—14-jointed antennæ.

Ten green bugs used, five green bugs parasitized. Five parasites emerge; all were males, with 14-jointed antennæ.

Experiment No. 65.—*April 10 to May 1, 1908.*

A single parasitized green bug placed in a vial.

April 10, female parasite emerged and placed in a breeding-cage with 25 green bugs which were free from parasites.

April 11, parasite active.

April 15, parasite dead.

April 18, green bugs turning yellow.

April 19, 4 dead green bugs.

April 20, 16 dead green bugs.

April 21, 5 dead green bugs.

April 23, 6 parasites emerged—6 males; 6 males, 15-jointed antennæ, last joint 2 times as long as thick.

April 24, 9 parasites emerged—9 males; 9 males, 15-jointed antennæ, last joint 2 times as long as thick.

April 25, 5 parasites emerged—5 males; 5 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 27, 3 parasites emerged—1 male, 2 females; 1 male, 14-jointed antennæ, last joint 2 times as long as thick; 2 females, 13-jointed antennæ, last joint 2½ times as long as thick.

April 28, 1 parasite emerged—1 male; 1 male, 14-jointed antennæ, last joint 2 times as long as thick.

April 29, 1 parasite emerged—1 male; 14-jointed antennæ.

April 30, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint 1½ times as long as thick.

Twenty-five green bugs were used and twenty-seven parasitized. The two extras were offspring of the original number used. Twenty-seven parasites emerged, of which two were females with normal antennæ. Six of the males had 14-jointed antennæ and eighteen males had 15-jointed antennæ.

Experiment No. 66.—*April 10 to May 1, 1908.*

A single parasitized green bug placed in a vial.

April 10, female parasite emerged and was placed in a test-tube with 30 green bugs which were free from parasites. A cloth was fastened over the end of the tube so that it was impossible for bugs to get out or in. The green bugs were fed from day to day on wheat free from both parasites and green bugs.

April 15, parasite dead.

April 18, a number of green bugs turning yellow.

April 19, 11 dead green bugs.

April 20, 10 dead green bugs.

April 21, 7 dead green bugs.

April 23, 6 parasites emerged—6 males; 6 males, 15-jointed antennæ, last joint as long as thick.

April 25, 11 parasites emerged—11 males; 11 males, 15-jointed antennæ, last joint as long as thick.

April 26, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint as long as thick.

April 27, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint as long as thick.

April 28, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint 2 times as long as thick.

April 29, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ; last joint 2 times as long as thick.

April 30, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint 2 times as long as thick.

Thirty green bugs were used and twenty-eight bugs parasitized. Twenty-seven parasites emerged. All were males, with 15-jointed antennæ.

Experiment No. 67.—*April 10 to May 1, 1908.*

A single parasitized bug placed in a vial.

April 10, female *Lysiphlebus* emerged and was placed in a test-tube with 20 unparasitized green bugs. A piece of cloth was fastened over the end of the tube so that it was impossible for bugs to get in or out. The green bugs were fed from day to day with wheat free from green bugs and parasites.

April 15, parasite dead.

April 18, bugs turning yellow.

April 17, 10 dead bugs.

April 20, 11 dead bugs.

April 23, 5 parasites emerged—5 males; 3 males, 14-jointed antennæ, last joint 2 times as long as thick; 2 males, 15-jointed antennæ, last joint as long as thick.

April 24, 3 parasites emerged—3 males; 3 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 25, 5 parasites emerged—5 males; 5 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 27, 5 parasites emerged—5 males; 5 males, 14-jointed antennæ, last joint 2 times as long as thick.

April 29, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint as long as thick.

April 31, 1 parasite emerged—1 male; 1 male, 15-jointed antennæ, last joint as long as thick.

Twenty green bugs were used. Twenty-one bugs parasitized. All parasites emerged were males. There were sixteen with 14-jointed antennæ, and five with 15-jointed antennæ.

Experiment No. 68.—*April 15 to May 1, 1908.*

A single parasitized green bug placed in a vial.

April 15, female parasite emerged and was placed in a breeding-cage with 20 green bugs unparasitized.

April 18, parasite dead.

April 20, green bugs turning yellow.

April 22, 6 green bugs dead.

April 23, 11 green bugs dead.

April 24, 3 green bugs dead.

April 28, 2 parasites emerged—2 males; 2 males, 15-jointed antennæ, last joint half as long as thick.

April 29, 9 parasites emerged—9 males; 5 males, 15-jointed antennæ, last

joint as long as thick; 2 males, 14-jointed antennæ, last joint 2 times as long as thick; 2 males, 14-jointed antennæ, last joint 1½ times as long as thick.

April 30, 3 parasites emerged—3 males; 3 males, 15-jointed antennæ, last joint 1½ times as long as thick.

May 1, 5 parasites emerged—5 males; 4 males, 15-jointed antennæ, last joint as long as thick; 1 male, 16-jointed antennæ, last joint half as long as thick.

Twenty green bugs were used and twenty parasitized. From these seventeen parasites emerged. All were males. There were twelve males with 15-jointed antennæ, four with 14-jointed antennæ, and one with 16-jointed antennæ.

From 352 parthenogenetic offspring, 339 were males and 13 females. Of the males 203 had 15-jointed antennæ, 131 had 14-jointed antennæ, and 5 had 16-jointed antennæ. Of the 13 females, 8 had 13-jointed antennæ and 5 had 12-jointed antennæ.

EXPERIMENTS SHOWING EFFECT OF THE *Lysiphlebus tritici* ON APHIDS OTHER THAN THE GREEN BUG.

May 2 to May 9, 1908.

Macrosiphum granaria from the field to determine whether they have been parasitized:

May 2, 20 *Macrosiphum granaria* brought from field to determine whether they were parasitized.

May 5, 1 parasite emerged; 1 female *Lysiphlebus tritici.*

May 9, 1 parasite emerged; 1 female *Lysiphlebus tritici.*

The *Macrosiphum* in this experiment were kept in a room where parasites had not been bred, so they must have been parasitized in the field. This experiment shows that *Lysiphlebus triciti* were at work in the fields about Lawrence during the month of May.

1B.—*March 26 to April 17, 1908.*

Lysiphlebus triciti placed with *Macrosiphum granaria* to determine whether the *Macrosiphum* will become parasitized:

March 26, 20 winged *Macrosiphum granaria* placed in a breeding-cage with 3 female parasites.

March 30, parasites dead.

April 7, 1 dead *granaria.*

April 15, 1 parasite emerged.

April 17, no parasitized *Macrosiphum.*

Twenty winged *Macrosiphum granaria* were used in this experiment; one adult was parasitized and one parasite emerged.

2B.—*March 31 to April 21, 1908.*

March 31, 30 *Macrosiphum granaria* placed in a breeding-cage with 3 pairs of parasites.

April 4, parasites dead.

April 14, 7 *Macrosiphum* dead.

April 16, 1 parasite emerged.

April 17, no parasites emerged.

April 18, 3 parasites emerged.
April 20, 2 parasites emerged.
April 21, no parasites emerged.

Thirty *Macrosiphum granaria* were used in this experiment. Seven were parasitized and five parasites emerged.

3B.—*April 1 to May 2, 1908.*

April 1, 50 *Macrosiphum granaria* placed in a breeding-cage with 3 pairs of parasites.
April 6, parasites dead.
April 22, 11 dead *Macrosiphum.*
April 24, 1 dead *Macrosiphum.*
April 29, 2 parasites emerged.
April 30, 3 parasites emerged.
May 1, 4 parasites emerged.
May 2, no parasites emerged.

Fifty *Macrosiphum granaria* were used in this experiment. Twelve were parasitized and nine parasites emerged.

4B.—*April 2 to May 2, 1908.*

April 2, 50 *Macrosiphum granaria* placed in a breeding-cage with 10 female parasites.
April 7, parasites dead.
April 13, 4 dead *Macrosiphum.*
April 14, 15 dead *Macrosiphum.*
April 15, 1 dead *Macrosiphum.*
April 22, 1 parasite emerged.
April 23, 2 parasites emerged.
April 24, 3 parasites emerged.
April 25, 2 parasites emerged.
April 29, 4 parasites emerged.
May 2, no parasites emerged.

Fifty *Macrosiphum granaria* were used in this experiment. Twenty were parasitized, and twelve parasites emerged. All the *Macrosiphum* parasitized were young, being about the third moult when they died. None of the adults were parasitized.

5B.—*April 4 to May 2, 1908.*

April 4, 4 female parasites placed in a breeding-cage with 50 *Macrosiphum granaria.*
April 9, parasites dead.
April 14, 10 dead *Macrosiphum.*
April 24, 13 dead *Macrosiphum.* No parasites have emerged.
April 26, 4 parasites emerged.
April 27, 2 parasites emerged.
April 29, 3 parasites emerged.
April 30, 5 parasites emerged.
May 1, 1 parasite emerged.
May 2, no parasites emerged.

Fifty *Macrosiphum* were used. Twenty-three were parasitized and fifteen parasites emerged. All *Macrosiphum* parasitized were small, being about the third moult when they died.

Experiments to determine whether *Lysiphlebus tritici* prefers to parasitize *Toxoptera graminum* or *Macrosiphum granaria:*

March 24 to April 7, 1908.

March 24, 10 green bugs and 10 *granaria* were placed in a breeding-cage with a single pair of parasites.

March 28, parasites dead.

March 30, 7 green bugs dead.

March 31, 1 green bug dead; 1 *granaria* dead.

April 1, 2 green bugs dead; 2 *granaria* dead.

April 3, 5 parasites emerged—2 males, 3 females.

April 4, 4 parasites emerged—4 females.

April 6, 4 parasites emerged—4 females.

Ten green bugs and three *Macrosiphum granaria* were parasitized. Thirteen parasites emerged, of which two were males and eleven females. The progeny of the original twenty were removed from day to day, so that only the original number counted in this experiment.

April 2 to May 2, 1908.

April 2, 15 green bugs and 15 *Macrosiphum granaria* were placed in a breeding-cage with a single pair of parasites.

April 6, parasites dead.

April 11, 7 dead green bugs.

April 13, 8 dead green bugs; 1 dead *granaria.*

April 22, 5 parasites emerged—3 males, 2 females.

April 23, 9 parasites emerged—2 males, 7 females.

April 24, no parasites emerged.

May 2, no parasites emerged.

Thirty aphids were used in this experiment: Fifteen green bugs and fifteen *granaria.* All of the green bugs and one *granaria* parasitized. Fourteen parasites emerged, of which 5 were males and 9 females.

April 4 to May 2, 1908.

April 4, 10 green bugs and 10 *Macrosiphum granaria* were placed in a breeding-cage with a single pair of parasites.

April 8, parasites dead.

April 17, 5 dead green bugs; *granaria* healthy.

April 18, 4 dead green bugs; *granaria* healthy.

April 20, 1 dead green bug.

April 25, all *granaria* healthy.

April 26, 4 parasites emerged—1 male, 3 females.

April 27, 2 parasites emerged—2 females.

April 28, 4 parasites emerged—4 females.

May 2, no *granaria* parasitized.

Ten green bugs and ten *Macrosiphum granaria* were used in this experiment. All the green bugs were parasitized but all *granaria* were healthy May 2. Ten bugs were parasitized. Ten parasites emerged—nine females and one male.

April 22 to May 7, 1908.

April 22, 20 green bugs and 20 *Macrosiphum* were placed in a breeding-cage with two fertile female parasites.

April 25, parasites dead.
April 29, 7 green bugs dead.
April 30, 9 green bugs dead.
May 2, 4 green bugs dead; 3 *granaria* dead.
May 3, 4 parasites emerged—3 males, 1 female.
May 4, 10 parasites emerged—2 males, 8 females.
May 6, 3 parasites emerged—3 females.
May 7, 1 parasite emerged—1 female.

Forty aphids used; twenty-three parasitized. Eighteen parasites emerged, of which thirteen were females and five males. Three *Macrosiphum granaria* were parasitized.

Lysiphlebus tritici placed with the pansy aphis to determine whether they will become parasitized:

March 31 to April 14, 1908.

March 31, 15 pansy aphis placed in a breeding-cage with 3 pairs of parasites.
April 4, parasites dead.
April 14, no aphis parasitized.

February 28 to March 30, 1908.

Lysiphlebus tritici placed in a breeding-cage with *Macrosiphum chrysanthemicolen* to determine whether the *Macrosiphum* will become parasitized:

February 28, 10 female parasites placed in a breeding-cage with a number of *Macrosiphum chrysanthemicolen.*
March 2, parasites dead.
March 30, no *Macrosiphum* parasitized.

March 9 to March 30, 1908.

March 9, 10 female parasites put in a breeding-cage with 10 *Macrosiphum chrysanthemicolen.*
March 11, parasites dead.
March 30, no *Macrosiphum* parasitized.

The *Lysiphlebus* used in the experiment emerged March 9. They had never been with aphis and had no opportunity of ovipositing.

March 24 to April 19, 1908.

Lysiphlebus tritici placed in a breeding-cage with *Chaitophorus populicola* to determine whether they will become parasitized:

March 24, 10 female *Lysiphlebus* placed in a breeding-cage with about 200 *Chaitophorus populicola.*
March 31, parasites dead.
April 19, no *Chaitophorus* parasitized.

The *Lysiphlebus* were observed attempting to oviposit but no parasitized bugs were found and no parasites emerged.

March 9 to April 7, 1908.

Lysiphlebus tritici placed in a breeding-cage with *Chaitophorus*

populicola to determine whether the *Chaitophorus* will become parasitized:

March 9, 10 female *Lysiphlebus* placed in a breeding-cage with about 200 *Chaitophorus populicola*. During the time the experiment was observed the *Lysiphlebus* made several attempts to oviposit on the *Chaitophorus*.

March 14, parasites dead.

April 7, no *Chaitophorus* parasitized.

May 6 to May 28, 1908.

Lysiphlebus tritici placed in a breeding-cage with *Siphocoryne avenæ* to determine whether the *Siphocoryne* will become parasitized:

May 6, 10 *Siphocoryne avenæ* were placed in a breeding-cage with a single pair of parasites.

May 11, parasites dead.

May 15, 1 dead bug.

May 16, 4 dead bugs.

May 18, 5 dead bugs.

May 20, 1 parasite emerged—1 male.

May 21, 2 parasites emerged—2 females.

May 23, 7 parasites emerged—1 male, 6 females.

Ten *Siphocoryne* were used. Ten were parasitized and ten parasites emerged. The parasites had just emerged when they were placed with the *Siphocoryne*.

May 6 to May 23, 1908.

May 6, 10 *Siphocoryne avenæ* free from parasites were placed in a breeding-cage with a single pair of parasites.

May 11, parasites dead.

May 14, 2 dead bugs.

May 16, 8 dead bugs.

May 20, 2 parasites emerged—2 males.

May 21, 3 parasites emerged—3 females.

May 23, 5 parasites emerged—1 male, 4 females.

Ten *Syphocoryne* were used in this experiment. Ten were parasitized and ten parasites emerged. The parasites used in this experiment had just emerged and had not been with the green bug.

April 22 to May 15, 1908.

Lysiphlebus tritici and *Macrosiphum trifolii* placed in the same breeding-cage to determine whether the *Macrosiphum* will become parasitized:

April 20, 10 parasites—5 males and 5 females—placed in a breeding-cage with 20 *Macrosiphum trifolii*.

April 23, parasites dead; removed these and others put in their place.

April 24, parasites dead. Most of the *Macrosiphum trifolii* found dead on the under side of the leaves. Death due to the fungus *Entomophorora aphidis*.

April 24, 20 green bugs were placed in the breeding-cage with the dead *Macrosiphum*.

May 15, no green bugs dead from fungus.

April 20 to May 15, 1908.

Lysiphlebus tritici placed in breeding-cage with *Macrosiphum trifolii* to determine whether the *Macrosiphum* will become parasitized:

April 20, 5 pairs of parasites placed with 40 *Macrosiphum trifolii.*

April 21, parasites dead; others put in.

April 22, parasites dead.

The *Macrosiphum* were dead on the under side of the leaf. They were found to have died from the effect of the fungus *Entomophorora aphidis.*

April 23, 20 green bugs were placed in the same breeding-cage with the dead *Macrosiphum*, but none were affected by the fungus on May 15. The 20 green bugs were present in a healthy condition.

April 18 to May 10, 1908.

Chaitophorus negundinis from the elm placed in a breeding-cage with *Lysiphlebus tritici* to determine whether they will be parasitized:

April 18, 20 *Chaitophorus negundinis* placed in a test-tube with 5 male and 5 female parasites. The end of the tube was covered with cloth so that no forms could escape. The *Chaitophorus* were fed from day to day.

April 23, no *Chaitophorus* parasitized.

April 30, no *Chaitophorus* parasitized.

May 10, no *Chaitophorus* parasitized.

May 10 the *Chaitophorus* were as healthy as when the experiment began. The parasites used in this experiment were selected from a breeding-cage free from green bugs, so they could have had no place to oviposit their eggs.

April 18 to May 10, 1908.

Chaitophorus negundinis from the elm were placed in a breeding-cage with *Lysiphlebus tritici* to see if the *Chaitophorus* would be parasitized:

April 18, 20 *Chaitophorus negundinis* were placed in a breeding-cage with 5 male and 5 female parasites.

April 23, all parasites dead.

April 30, no *Chaitophorus* parasitized.

May 10, all *Chaitophorus* present; no parasitized forms.

The *Lysiphlebus* was watched for some time after being placed with the *Chaitophorus* and no attempt was made to oviposit. When they came in contact the parasite would fly away.

ORIGINAL DESCRIPTION.

Lysiphlebus tritici Ashm.

♀ AND ♂. Length, 1⅛ mm. Back smooth, polished; metathorax smooth, black, with delicate lateral ridges; legs, including coxæ, honey-yellow, the posterior femora sometimes pale brownish; abdomen as usual, brownish piceous, the petiole honey-yellow, slightly

widened posteriorly; wings hyaline, the stigma and veins pale brown, the second branch of the radius as long as the first.

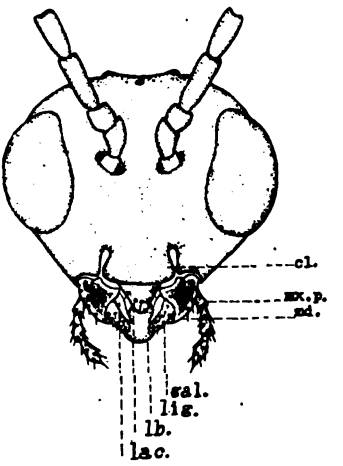


FIG. 44. *Lysiphlebus tritici*. Cephalic view of the head. Cl., Clypeus; Lb., Labrum; Md., Mandible; Mx. P., Maxillary Palpus; Gal., Galea; Lac., Lacinia; Lig., Ligula. Greatly magnified. (Original.)

The antennæ in the ♀ are 13-jointed, brown, the joints of the flagellum about twice as long as thick, the terminal joints about one-third longer than the preceding. The ♂ has 14-jointed antennæ, the joints of the flagellum about two and a half times as long as thick, the terminal joint being longer and thicker than the others; the abdomen is brown-black at apex, the petiole and the basal portion of the third segment honey-yellow or pale yellow ferruginous; the hind tarsi about as long as their tibia, the basal joint being about as long as the three following joints.

Habitat, Cadet, Mo. Described from several specimens received from Mr. J. W. Barlow, labeled number 2721, reared June 20, 1882, from wheat aphis, *Aphis avenæ*. (Proceedings of the National Museum, 1888, p. 668, by Ashmead.)

VARIATIONS IN THE NUMBER OF JOINTS IN THE ANTENNÆ OF THE *Lysiphlebus tritici*.

16B.—*March 9 to March 23, 1908.*

A male parasite with 15-jointed antennæ and a female parasite with 13-jointed antennæ, each having emerged from a dead green bug, isolated in separate vials, and now placed in a breeding-cage with *Toxoptera graminum* to determine the variations in number of joints of the antennæ in the offspring.

March 9, this single pair of parasites put in with 50 green bugs.

March 17, 1 parasite emerged—1 female; 1 female, 13-jointed antennæ, last joint 2½ times as long as thick.

March 18, 6 parasites emerged—6 females; 4 females with 13-jointed antennæ, last joint 2½ times as long as thick; 2 females, 12-jointed antennæ, last joint 3 times as long as thick.

March 19, 8 parasites emerged—1 male, 7 females; 1 male, 15-jointed antennæ, last joint as long as thick; 3 females, 13-jointed antennæ, last joint 3 times as long as thick; 1 female, 13-jointed antennæ, last joint 2½ times as long as thick; 1 female, 13-jointed antennæ, last joint 1½ times as long as thick; 2 females, 12-jointed antennæ, last joint 2 times as long as thick.

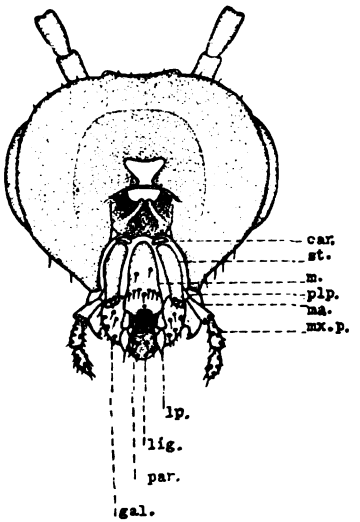


FIG. 45. *Lysiphlebus tritici.* Caudal view of the head. Car., Cardo; St., Stipes; Plp., Palpifer; Mx. P., Maxillary Palpus; Gal., Galea; Ma., Mandible; M., Mentum; L. P., Labial Palpus; Lig., Ligula; Par., Paroglossa. Greatly magnified. (Original.)

March 20, 6 parasites emerged—3 males, 3 females; 2 males, 15-jointed antennæ, last joint 1½ times as long as thick; 1 male, 14-jointed antennæ, last joint 2 times as long as thick; 2 females, 13-jointed antennæ, last joint 2½ times as long as thick; 1 female, 12-jointed antennæ, last joint 2 times as long as thick.

March 21, 10 parasites emerged—10 females; 8 females, 13-jointed antennæ, last joint 2½ times as long as thick; 2 females, 12-jointed antennæ, last joint 3 times as long as thick.

March 23, 3 parasites emerged—3 females; 3 females, 13-jointed antennæ, last joint 2½ times as long as thick.

Fifty green bugs were used in this experiment. Thirty-four parasites emerged. Thirty of all parasites emerged were females, of which seven had 12-jointed antennæ, twenty-three had 13-jointed antennæ. Of the males, three had 14-jointed antennæ and one had 15-jointed antennæ.

17B.—*March 10 to March 23, 1908.*

March 10, 25 green bugs placed in a breeding-cage with a single pair of parasites, each having emerged from a dead green bug isolated in separate vials.

March 19, 4 parasites emerged—4 males; 2 males, 15-jointed antennæ, last joint 1½ times as long as thick; 2 males, 14-jointed antennæ, last joint 2 times as long as thick.

March 20, 1 parasite emerged—1 female; 1 female 13-jointed antennæ, last joint 2 times as long as thick.

March 23, 12 parasites emerged—7 males, 5 females; 1 female, 13-jointed antennæ, last joint 2½ times as long as thick; 2 females, 12-jointed antennæ, last joint 3 times as long as thick; 2 females, 13-jointed antennæ, last joint 2½ times as long as thick; 7 males, 14-jointed antennæ, last joint 2 times as long as thick.

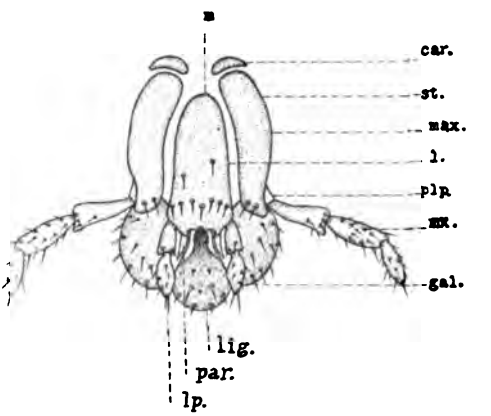


FIG. 46. *Lysiphlebus tritici.* Caudal view of the mouth parts. Max., Maxilla; Car., Cardo; St., Stipes; Gal., Galea; Plp., Palpifer; Mx. P., Maxillary Palpus; L., Labium; M., Mentum; Lig., Ligula; Par., Paraglossa; L. P., Labial Palpus. Greatly magnified. (Original.)

Twenty-five green bugs were used. Seventeen parasites emerged. Out

of the seventeen parasites eleven were males, of which but two had 15-jointed antennæ, the others having 14-jointed antennæ. Of the females three had 13-jointed antennæ and three had 12-jointed antennæ.

21B.—*March 24 to April 7, 1908.*

March 24, 16 winged *Toxoptera graminum* put in a test-tube with a single pair of parasites bred in isolation, to determine variation in the number of joints of the antennæ.

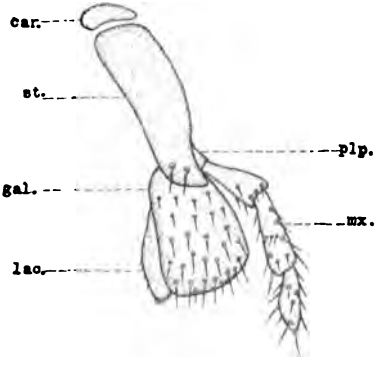


FIG. 47. *Lysiphlebus tritici.* Caudal view of a Maxilla; Car., Cardo; St., Stipes; Gal., Galea; Lac., Lacinia; Plp., Palpifer; Mx. P., Maxillary Palpus. Greatly magnified. (Original.)

April 3, 3 parasites emerged—2 males, 1 female; 1 female, 13-jointed antennæ, last joint 2½ times as long as thick; 1 male, 14-jointed antennæ, last joint 2 times as long as thick; 1 male, 15-jointed antennæ, last joint 1½ times as long as thick.

April 4, 6 parasites emerged—3 males, 3 females; 3 females, 13-jointde antennæ, last joint 2½ times as long as thick; 3 males, 15-jointed antennæ, last joint 2 times as long as thick.

April 6, 6 parasites emerged—1 male, 5 females; 1 male, 14-jointed antennæ, last joint 2 times as long as thick; 4 females, 13-jointed antennæ, last joint 2½ times as long as thick; 1 female, 12-jointed antennæ, last joint 2½ times as long as thick.

April 7, 3 parasites emerged—3 females; 3 females, 13-jointed antennæ, last joint 2½ times as long as thick.

Sixteen green bugs were used. Eighteen parasites emerged. Of these six were male, four of which had 15-jointed antennæ and two had 14-jointed antennæ. Twelve females emerged, eleven of which had 13-jointed antennæ, and one had 12-jointed antennæ.

a *b*

FIG. 48. *Lysiphlebus tritici.* Lateral view of caudal extremity of (*a*) female, (*b*) male. Greatly magnified. (Original.)

TABLE XXXVIII.

VARIATIONS IN THE NUMBER OF JOINTS OF THE ANTENNÆ OF THE FEMALE *LYSIPHLEBUS TRITICI*.

No.	No. of joints of antennæ.	Last joint times as long as thick.	No.	No. of joints of antennæ.	Last joint times as long as thick.
1	13	2	60	13	2
2	13	2	61	13	1½
3	13	2	62	13	3
4	13	1½	63	12	4
5	13	1½	64	12	4
6	13	2	65	12	2
7	13	1	66	13	4
8	13	2	67	13	2
9	13	2	68	12	2
10	13	2	69	13	2
11	12	3	70	13	2
12	13	2	71	13	2½
13	13	1½	72	13	2
14	13	3	73	13	2
15	13	3	74	13	2½
16	13	2	75	13	3
17	13	2	76	13	2
18	12	2	77	13	2
19	13	2	78	12	2
20	13	2	79	13	2
21	13	4	80	13	2
22	13	2	81	13	2
23	13	3	82	13	2
24	13	3	83	13	2
25	13	2	84	13	2
26	13	2	85	13	2
27	12	3	86	13	2
28	13	1	87	13	2
29	13	2	88	13	2
30	13	2	89	13	3
31	13	2	90	13	2
33	13	2	91	13	2
34	13	2	92	13	2
35	13	1	93	13	2
36	13	1	94	13	2
37	13	3	95	13	2
38	13	2	96	13	2
39	13	1	97	13	2
40	13	2	98	12	3
41	13	1	99	12	2
42	12	1½	100	13	2
43	13	3	101	13	2
44	13	2	102	13	2
45	13	1	103	13	3
46	13	1	104	13	2
47	13	2	105	13	2
48	13	3	106	13	2
49	13	2	107	13	2
50	13	2	108	13	2
51	13	2	109	13	2
52	13	2	110	13	2
53	13	2½	111	13	3
54	13	2	112	12	2
55	13	2	113	12	4
56	13	3	114	13	3
57	12	1	115	13	2½
58	13	2	116	12	2
59	13	2	117	13	3

TABLE XXXVIII—CONCLUDED.

No.	No. of joints of antennæ.	Last joint times as long as thick.	No.	No. of joints of antennæ.	Last joint times as long as thick.
118	13	2	130	13	2
119	13	2	131	13	2
120	13	2	132	13	2
121	13	2	133	13	2
122	13	2	134	13	2
123	13	2	135	13	2
124	12	2	136	13	2
125	12	3	137	13	2
126	13	3	138	13	2
127	13	2	139	13	2
128	12	3	140	12	3
129	13	2			

TABLE XXXIX.

VARIATIONS IN THE NUMBER OF JOINTS OF THE ANTENNÆ OF THE MALE *LYSIPHLEBUS TRITICI.*

No.	No. of joints of antennæ.	Last joint times as long as thick.	No.	No. of joints of antennæ.	Last joint times as long as thick.
1	14	2½	31	14	3
2	14	2½	32	14	3
3	14	2½	33	14	2
4	15	2½	34	15	1
5	14	2	35	14	2
6	14	2	36	14	2
7	14	2	37	14	2
8	14	1½	38	15	1
9	15	1	39	14	2
10	14	3	40	15	1
11	14	3	41	14	2
12	15	1	42	15	2
13	14	2	43	14	2
14	14	1	44	14	2
15	14	3	45	14	2
16	14	3	46	15	1
17	14	2½	47	14	2
18	14	2	48	14	2
19	15	1	49	14	2
20	15	1	50	14	2½
21	15	1	51	15	2
22	14	1	52	14	1
23	15	1	53	14	2
24	15	1	54	14	1
25	14	2	55	14	1
26	14	2	56	14	2
27	15	2	57	15	2
28	14	1	58	14	2
29	14	2	59	14	2
30	14	3	60	15	1

Out of 200 *Lysiphlebus tritici* examined 140 were females, 20 of which had 12-jointed antennæ and 120 had 13-jointed antennæ. Out of 60 males, 25 had 15-jointed antennæ and 35 had 14-jointed antennæ. This shows the variations greater in the male than in the female.

GENERAL SUMMARY.

On the distribution of the host, *Toxoptera graminum*, and its parasite, *Lysiphlebus tritici*, the host existed in unusual numbers, unattended by the parasite, over certain areas examined in Texas in 1906–'07, in Kansas in 1907, in Washington, D. C., in 1908, and in Oklahoma in 1909, during a sufficient period of time, over an adequate area, and under other conditions favorable to the natural distribution of the parasite.

The host then distributes itself more rapidly than the parasite, and succeeds in existing and increasing in unusual numbers free from the parasite.

Parasites transported and introduced into areas previously free from the parasite become active in the reduction of the green bug.

In view of these facts, the artificial distribution of the parasite becomes practical.

THE HOST, *Toxoptera graminum*.

During summer temperature in the experimental laboratory the average length of life, based on continuous observation, from birth to death, of 15 green bugs, was 35.22 days; average number of offspring, 55.42; average period of reproduction, 22.74 days; average number reproduced daily during reproductive period, 2.43; age at which reproduction begins, 7.1 days; number of moults, 4.

This data was corroborated in an observation upon 54 green bugs selected at various ages and kept under similar conditions.

The rate of reproduction in the winged form appears to be about the same as in the wingless form. The same ratio of reproduction and time of development attended those experiments conducted in the field and kept under observation during the same period.

During January and February, mean temperature 35° F., average daily number of young for each individual during the reproductive period was .374; during March and April, mean temperature 58° F., 1.5 during the reproductive period. Laboratory experiments from January to May, mean temperature 62.32° F., gave results corresponding to those of summer temperatures in the field and laboratory.

The lowest temperature at which offspring appeared was during a day recorded maximum 36° F., and minimum 4° F. Under artificial conditions offspring were reproduced during a day of temperature 65° to 103° F.

The following forms of *Toxoptera graminum*, all of which may be the offspring of one agamic green bug, appear during the life cycle:

1. Apterous agamic females.
2. Winged agamic females.
3. Winged intermediate females, resembling the winged agamic females in antennal characteristics.
4. Winged intermediate females, resembling the true females in antennal characteristics.
5. Apterous intermediate females.
6. True females.
7. Males.
8. Stem mothers.

During the past two years the true sexes first appeared in both field and laboratory in October. The laboratory stock was kept without accessions from outside.

The parent of the true female and the intermediate forms may be either winged or wingless.

The males are the offspring of the wingless agamic females. Such females may produce both males, females and viviparous forms.

The intermediate forms belong to the sex generation and may be considered as an attempt toward the production of a perfect sexual individual. Apterous agamic females greatly outnumber all other forms.

A single agamic green bug under observation produced:

1. Apterous agamic females.
2. Winged agamic females.
3. Winged individual resembling the winged agamic female in some characteristics and the true female in other characteristics, and producing only living young.
4. Winged individuals, resembling the winged agamic females in some characteristics and the true female in others, and producing both living young and winter eggs.
5. Apterous individuals resembling the true female in external characteristics, and producing only living young.
6. Apterous individuals resembling the true female in external characteristics, and producing both living young and winter eggs.
7. True females.
8. Males.

Alternation of food plants is not essential.

The principal insect enemies of the green bug are the Syrphus

flies, the aphis lion, lady-bird beetle, and wasp-like parasite *Lysiphlebus tritici.*

THE PARASITE, *Lysiphlebus tritici.*

In laboratory experiments, the maximum number of green bugs parasitized by a single individual, was 95; average number, 38.

Length of life in laboratory 3 to 6 days. Minimum period of development in laboratory 7 days.

The ratio of male to female parasites is as 34 is to 65.

Lysiphlebus is also parthenogenetic, the off-spring being almost entirely composed of males.

Only one parasite develops in the body of the host.

Lowest temperature at which *Lysiphlebus* was observed attempting to oviposit was 35° F.

The antennæ of the female vary from 12 to 13 joints and of the male from 14 to 15 joints. Five parthenogenetic males had 16-jointed antennæ.

In the laboratory breeding-cages, *Lysiphlebus* parasitized a small percentage of *Macrosiphum granaria* and would parasite more freely *Siphocoryne avenæ* but would not parasitize *M. trifolii* nor *M. chrysanthemicolen* nor *Chaitophorus negundinis.* From field observation, however, it appears that *Lysiphlebus* does not perpetuate itself and maintain a general distribution on these other hosts.

THE INFLUENCE OF CLIMATE UPON THE GREEN BUG AND ITS PARASITE.

Toxoptera graminum and *Lysiphlebus tritici.*

By P. A. GLENN.

I.—CLIMATIC CONDITIONS AND *T. graminum.*

The green bug, like many other insects, is so influenced by climatic conditions, and so beset by natural enemies, that ordinarily it exists in such small numbers as to be unnoticed and harmless; but occasionally there occurs a season when climatic conditions are favorable and natural enemies few, and the green bug, because of its power to multiply rapidly, appears in countless numbers over large areas, and destroys thousands of acres of grain before its natural enemies gain the mastery over it or climatic conditions become so unfavorable as to exterminate it. Since its first appearance in the United States, twenty-five years ago, there have been three widespread outbreaks.

Many factors enter in to regulate the abundance of the green bug, chief of which is climatic conditions. It is the purpose of this discussion to point out as definitely as may be done what climatic conditions are favorable and what are unfavorable to the green bug, and to define if possible the limits between them.

I shall first discuss the various occurrences which have been reported and give the accompanying climatic conditions which seem to me to be most important—so far as I have been able to obtain them from the records of the United States Weather Bureau.

In the case of general outbreaks I have collected the data for places located in different states within the area of infestation, and in the cases of local outbreaks the data are from the nearest weather station for which the desired data could be secured. In each case it is important to determine from the reports of the various occurrences how long the green bug was present before it was first noted, and how long it continued. It is not always easy to do this with certainty, but from what we know of its habits we are able to supply information very often which the reports do not give.

When the green bugs are present in the spring they increase in numbers until the hot weather approaches. Then the winged forms take wing and drift with the wind. If the wind is in a favorable direction they are carried to cooler regions. The wing-

less forms apparently disappear, not to be seen again until fall. In the fall, when the temperature is falling, no migrations take place from one region to another, but the winged forms return from their summer food to the fall grain, develop the sexual forms, and, if the winter is severe, perish; if sufficiently mild they live throughout the winter and the following spring. The eggs which are laid in the fall, if they are like other species of plant-lice, hatch in March or April and begin the round of life anew. This being true, their presence in April or later may be due to either or all of three causes: (1) Eggs laid in the fall may hatch, (2) living bugs may survive the winter, and (3) winged forms may migrate thither from other infested regions. If they are reported in March or earlier it is evident that they have been present in the fall and have wintered over. And since migrations do not occur after the hot weather of summer, their presence in the fall is evidence that they have passed the summer there.

Since in the most important outbreaks they have been first observed in the winter or early spring, I have thought it best to begin the investigation of climatic conditions with the preceding summer. In preparing the charts to accompany this discussion I have made them in each case for the year beginning with the preceding July and ending with the June following. In these charts I have represented the monthly maximum and the monthly minimum temperatures by dots and dashes, the monthly means by continuous lines, and the monthly normals by dotted lines. At the upper part of the charts I have put the letter "P" to denote the months in which the green bugs were present, and "D" to denote the time they disappeared. "A" at the top denotes the absence of the bug. Near the bottom of the charts I have put the monthly precipitation, in inches.

THE FIRST OCCURRENCE IN THE UNITED STATES.

In June of 1884 the green bug made its appearance at Cabin John bridge, Maryland. It was not in destructive numbers, and it cannot be ascertained whether it had passed the winter there, hatched from eggs, or migrated from some other region farther south; so nothing much can be gained by a study of the temperatures in this case. It will be noted from chart No. 1 that at Washington, D. C., the maximum temperatures for the preceding July and August did not exceed 97° F. The minimum temperature for the winter months was 2° F. The mean temperature for January was 29.5° F, or 2½° below normal; for February about 6° above normal; for April and May somewhat above normal; and

for June, the time when they were reported, the temperature was normal. It is not probable that they passed the winter there. The fact that they were not discovered until June, and that they were in small numbers, would indicate that they either overwintered in the egg stage or else migrated from some region farther south.

THE OUTBREAK OF 1890.

As early as 1890 their presence in destructive numbers was reported at Jalapa, Monroe county, Tennessee, and Mebane, Alamance county, North Carolina; in February at Era, Cooke county, Texas; early in April at Denton, Denton county, Texas, and throughout the wheat belt of Texas and Oklahoma; in June at Cadet, Mo., and in southern Indiana, appearing as far north as La Fayette. From these reports it is certain that they must have been present in the fall in eastern Texas, eastern Tennessee and North Carolina, and bred in the fields throughout the winter. Their presence in the fall is evidence that they passed the previous summer in these regions.

PALESTINE, TEX., 1889–'90. Palestine, Tex., was the only place for which complete data could be secured for eastern Texas. Chart No. 2 gives the temperature-curves and precipitation for Palestine from July, 1889, to June, 1890. It will be noted that the maximum temperatures for July and August did not exceed 99° F. The minimum temperature for the winter months did not fall below 19° F. The mean for December was 64° F., or 14 degrees above normal; for January, 55.6°, or 9 degrees above normal; for February, 57.2°, or 7 degrees above normal. The temperature for the spring months was normal. The precipitation was abundant throughout the year.

JALAPA, MONROE COUNTY, TENNESSEE, 1889–'90. The nearest station to Jalapa, Monroe county, for which I could secure data, is Benton, Polk county, which borders Monroe county on the south. This chart, No. 4, shows that the highest summer temperature was only 91° F. The minimum temperature was in March and was 18° F. The mean temperature for the summer was below normal. For December, January and February the monthly means were 55° F., 51° F., and 53° F., or from 11 to 13 degrees above normal; for March, 48° F., or 2 degrees below normal. The only data in regard to precipitation were contained in the report of the United States Department of Agriculture, Bureau of Entomology Bulletin No. 38. This gave March as a wet month. In the report it was stated that the insects had not been able to survive the heavy rains

and frosts of March. It would seem from this that a temperature of 18° F. in rainy weather is sufficiently cold to kill the living forms in the field, although at Palestine, Tex., they survived a temperature of 19° F. with about five inches of rainfall. But it will be noted that the monthly means at Palestine, Tex., for the winter months were from 3 to 11 degrees higher than at Benton, which perhaps explains the difference in the results.

MEBANE, ALAMANCE COUNTY, NORTH CAROLINA. In regard to the climatic conditions in North Carolina, complete data could not be secured, but the maximum temperature recorded in the state for 1889 was 100° F. at Kitty Hawk, in the eastern division; so at Mebane the maximum was somewhat lower than 100° F. and the precipitation was above normal. The monthly mean temperatures for January and February at Pittsboro, located in an adjoining county, were 49.7° F. and 51° F. respectively, which is several degrees above normal, and the precipitation was 0.62 and 2.5 inches respectively, which is considerably below normal. No data could be obtained for March and April. The mean temperature at Pittsboro for May, 1890, was 66.8° F., which is about normal, and for June 76.9° F., which is about 3 degrees above normal.

In general, we may say that the maximum summer temperature did not reach 100° F.; the minimum did not fall below 20° F.; the spring months were about normal, the precipitation for the summer was above normal, and for the winter months below normal.

LA FAYETTE, IND. In the case of La Fayette, Ind. (chart No. 5), the maximum summer temperature did not exceed 95° F.; the minimum winter temperatures fell to —3° F., the monthly mean for December was 41° F.; for January, 33.5° F., and for February 34° F., or from 6 to 11 degrees above normal. The mean for March was 31° F., or 6 degrees below normal. I have no data in regard to precipitation. In view of the fact that in Tennessee the green bugs could not endure the wet March weather when the temperature was only 18° F., it is not probable that they passed the winter in the field as far north as La Fayette, where the temperature went to —3° F. The late occurrence of the pest in this locality indicates that they came either from the winter egg or migrated from some point farther south.

In general, we may say for the year 1889–'90 that throughout the area of infestation the summer of 1889 was characterized by low maximum temperatures, and in Tennessee and Indiana the monthly means for the summer were much below normal. There were no low temperatures during the winter months, and the

monthly means were much above the monthly normals. March was slightly below normal, except in Texas; the other spring months were normal. The green bugs lived in the fields where the monthly means were 50° F. or above, but were not reported at La Fayette, Ind., until June, where the monthly means for the winter months ranged between 31° F. and 41° F.

OCCURRENCES IN 1890–'91.

The reports at hand do not indicate when the green bugs disappeared in the above localities. Some reports indicate that they were present in some localities in Texas in the spring of 1891. Chart No. 3 shows that at Palestine, Tex., the maximum summer temperature was 97° F.; the minimum winter temperature was 21° F.; March, 1891, was about 8 degrees below normal, and the other months about normal. The rainfall was quite abundant. The only marked departure from the normal was the rainfall of January, which was 11.11 inches.

THE OUTBREAK OF 1901.

TEXAS. This outbreak really began in the spring of 1900, in Texas. They were present in Cooke county, Texas, and in injurious numbers, that spring. They were reported in December following and continued to breed throughout the winter and spring, nearly up to June, when they disappeared. Chart No. 6, for Fort Worth, Tex., shows that the maximum summer temperature did not exceed 97° F., and the monthly means for July and August were 80.8° F. and 81.1° F., or from 2 to 3 degrees below normal; the minimum winter temperature did not fall below 15° F.; the monthly means for December and January were 49° F. and 50° F., or from 2 to 6 degrees above normal; for February, the mean was 45° F., or 3 degrees below normal, and for April and May from 2 to 2½ degrees below normal. The report of the United States Weather Bureau also shows that there was an excess of rain during the summer months of 1900 and a great deficiency of rain during the winter and spring of 1901.

OKLAHOMA. The presence of the green bug was not reported during the winter months in Oklahoma, but they were present there in April, 1901, though in less destructive numbers than in Texas; so it is impossible, with the present data, to tell just how far north they were able to winter over. It is probable that some lived through the winter in southern Oklahoma, but not so far north as Kingfisher. Chart No. 8 gives the temperatures for Kingfisher, Okla., for 1900 and 1901. It will be noted that in August the maximum reached 107° F., and the precipitation was very de-

ficient; the winter minimum was 6° F., and the monthly means ranged between 37.5° F. and 41.5° F. The temperatures for the spring months were somewhat below normal. March and April were rather dry months, and May wet.

Reports show that about the middle of May, 1901, the green bugs began to disappear from Texas. The winged forms took flight, drifting northward, and the wingless forms must have been destroyed by the parasites or some other cause. In Bulletin 38, United States Department of Agriculture, Bureau of Entomology, is this paragraph: "In a communication of May 14, Mr. W. E. Campbell, of Ralli Bros.' Agency, Greenville, Tex., stated that a few days previous to writing the weather became quite warm, causing the insect to leave that section and go farther north. They appear to be better suited to cold, damp weather. A number of fields in that vicinity were visited, where the insects had been particularly troublesome, without finding a single specimen at that time, the warmer weather apparently having driven them out of the country."

It will be noted (chart No. 4) that the maximum for May was 95° F. In this connection it will be of interest to refer to charts Nos. 7 and 9, for Fort Worth and Kingfisher, for the year 1901–'02, and note the extremely high temperatures of July and August. And aside from being very hot months, the report of the United States Weather Bureau shows that they were also dry months, especially in Texas. It would seem that the extremely hot, dry summer which followed the outbreak of 1901 had much to do with the destruction of the pest. In Texas the summer temperatures for 1901 were not so high as farther north, and one report (Bull. 38, Bureau of Ent., U. S. Dept. of Agr., p. 10) indicates that in some localities they were present in Texas in 1902.

In general, we may say that in Texas, where the green bug was present throughout the summer of 1900 and winter of 1900–'01, the summer months were unusually cool and moist; the winter months, with the exception of February, were warm and dry, and April and May were cool and moist. In Oklahoma the departures from the normal were not very great; the maximum for August was high, the winter months slightly above normal, and the spring months cool.

THE OUTBREAK OF 1907.

There is little doubt that one of the main factors in bringing about this destructive outbreak was, as pointed out by Mr. Webster (Cir. No. 93, U. S. Dept. of Agr., Bureau of Ent., p. 6), the unusually mild winter weather which prevailed throughout the

Mississippi valley, enabling the green bug to breed in the fields throughout the winter in some localities; and to this I would add the unusually cool, wet summer which preceded, making it possible for them to flourish during the summer and appear in the fall and winter in destructive numbers.

It is known from reports that they were present in the vicinity of Lawrence, Kan., in December, 1906, and they were present in destructive numbers in north central Texas in January, 1907; but it is impossible to determine just how far north they were able to live through the winter.

According to Mr. Webster's report (circular 93), they were present at Summers, Ark., some time previous to March 6, for they had destroyed the wheat in spots in the fields in that locality on that date. The same report shows that they must have been present in Oklahoma in March; hence there is little doubt that they passed the winter there. It is possible also that some passed the winter in the southern part of Kansas; but farther north they did not appear in destructive numbers until the migrations began, so that their presence in Kansas was probably due to the hatching of the spring brood and to migrations from the south.

The climatic conditions in east central Texas, Oklahoma and northeast Kansas are shown in charts Nos. 10, 12 and 14.

FORT WORTH, TEX. It will be seen by chart No. 10 that at Fort Worth the preceding July and August were cool months. The maximum for July was 99° F. and for August 94° F. Out of forty-one stations reported by the United States Weather Bureau in eastern Texas only sixteen reported temperatures higher than 99° F. and only six higher than 100° F.; and for August only three report temperatures of 100° F. or above, and the monthly mean was about 3 degrees below normal. The same report shows also that the precipitation for this part of the state for these months was above normal at every station.

The temperature for the winter months was much above normal. The lowest temperature at Fort Worth was 20° F., and the monthly mean did not fall below 52° F. At most of the stations it was higher than this. The precipitation for the winter and spring was much below normal. March was abnormally warm and April and May abnormally cold.

KINGFISHER, OKLA. Chart No. 12 shows that the character of the temperature at Kingfisher for the year was similar to that at Fort Worth. The summer maximum was 98° F.; the winter minimum was 10° F.; the lowest monthly mean was 43° F., and April

and May were abnormally cold. The United States Weather Bureau says, concerning July and August of 1906: "It was the coldest July during the last 15 years. The percentage of sunshine was much below normal. Rains occurred with unusual frequency." "August, cool and wet weather prevailed. . . . With one exception it was the coolest August during the last fifteen years." The precipitation for December was very slight over central and eastern Oklahoma; for January it was somewhat above normal, and for February, when the lowest temperatures were recorded, it was 1.07 inches. For March the precipitation was very slight, and for April, May and June abundant.

LAWRENCE, KAN. Chart No. 14 shows that the temperatures at Lawrence were very similar to those at Kingfisher, only the variations from the normal were not so great in the winter months as in either Oklahoma or Texas. The maximum temperature for July at Lawrence was 91° F. It was somewhat higher at most of the other stations in the state, but out of eighty-seven stations reporting only nine reported temperatures of 100° F. or above. The maximum for August was 93° F. Only twenty-five stations, mostly in the western division, reported temperatures of 100° F. or above. The minimum temperature at Lawrence was —2° F., and the lowest monthly mean 31° F. Nearly all the stations in the state reported temperatures below zero for February.

The precipitation for the summer months was abundant, and for the winter months below normal, except for January. The precipitation for March and April was deficient, and for May and June abundant. (See, also, chart No. 17, for climatic conditions at Wichita, Kan., 1906–'07.)

As compared with the year 1900–'01, the climatic conditions were very similar, but the departures from the normal during the winter and spring months was much greater in 1906–'07. This fact probably accounts, in a measure at least, for the greater extent and destructiveness of the last outbreak.

THE OCCURRENCES IN 1908.

So abundant and wide-spread were the green bugs in the spring of 1907 that farmers and grain men were very uneasy this spring, anticipating another outbreak of the pest; but their fears, fortunately, were not realized; for, strange as it may appear, so far as we are able to learn the green bug has occurred in but two localities this spring: The one in Leavenworth and Jefferson counties in northeast Kansas, and the other at Lakewood, N. M. Especially is this singular in view of the fact that last winter was an excep-

tionally mild one throughout the Mississippi valley. (See charts Nos. 11, 13, 15, and 18.)

What explanation are we to offer for this wide-spread destruction and apparently total annihilation of this pest where it was so abundant a year ago, and how did it happen that they escaped annihilation in northeast Kansas and southwest New Mexico? From the standpoint of climatic conditions the only explanation is to be found in the summer temperatures of 1907.

Chart No. 11 shows that the maximum temperature for July, 1907, at Fort Worth, Tex., was 101° F., or 2 degrees higher than for the same month in 1906; the maximum temperature for August, 1907, was 102° F., or 8 degrees higher than for the same month in 1906; for September, 1907, it was 101° F., or 6 degrees higher than for September, 1906. The rainfall for July, 1907, was slightly above normal, but for August and September much below normal; while for the same months in 1906 the precipitation for all three was abundant.

Chart No. 13 shows that the maximum temperatures at Kingfisher, Okla., for July, August, and September, 1907, were 101° F., 105° F., and 104° F. respectively, or 3, 9 and 10 degrees, respectively, higher than for the same months in 1906; and the rainfall for these months was less than half of what it was for the previous year.

Chart No. 15 shows that the maximum for Lawrence, Kan., for July, 1907, was 98° F.; for August, 95° F., and for September, 93° F. While these are higher than for the corresponding months of 1906, they are low as compared with the higher temperatures which prevailed in Texas, in Oklahoma, and in other sections of Kansas. The precipitation for July, August, and September, 1907, was nearly the same as in the corresponding months of 1906. In this part of the state, where the summer temperatures were low and the precipitation normal, a few green bugs succeeded in living through the summer, whereas in Texas, Oklahoma, and parts of Kansas where they were so abundant last spring, and where the summer was hot and dry, they were apparently annihilated. And indeed they barely escaped annihilation in this part of the state, for although in the spring they were present everywhere, they were found in the fall in only five fields, and in these only in protected localities, such as north slopes and the borders of fields protected by timber for at least part of the day. None were found on exposed south slopes. (Compare, also, charts Nos. 17 and 18, for Wichita, 1906–'07 and 1907–'08.)

It will be recalled that the summer that followed the spring outbreak of 1901 was also characterized by high temperatures similar to the summer of 1907, and the complete disappearance again of the pest lends aid to the theory that the hot, dry summer was responsible for it.

Not enough is known concerning the occurrence of the green bug in New Mexico to determine whether they passed the winter there or not. Specimens were received by this department on wheat from Lakewood. The number enclosed indicated that they were in large numbers, but the extent of the territory infested is not known at present. It is probable that they have been in that locality ever since the spring outbreak of a year ago.

Temperatures at different stations in New Mexico vary greatly, and one cannot be sure that the conditions at any station which may be selected represent anyway near accurately the temperature of the locality for which information is desired. Chart No. 16, for Roswell, has been selected as the one most likely to give the desired information. The maximum for June at Roswell was 104° F., but the mean for June was only 73.6° F. The maximum for July was 97° F., and for August 100° F. The mean for July and August was 77.9° F., and the precipitation slightly below normal. The means for November, December, January and February were 44.4°, 42.6°, 40.8° and 43.5°, and the minimum for these months was 12° F. The mean for March was 57° F., or about 6 degrees above normal. The precipitation for June was 2 03 inches, for July 1.74 inches, and for August 2.6 inches. These conditions are sufficiently within the range of the conditions which at other places have been found favorable for the surviving of the green bug through the summer and winter.

It seems to me that we are justified in making the general statement that wherever extremely high temperatures and deficient precipitation prevailed in the summer months of 1907 the green bug did not appear this year; and in those localities where it did appear this year the summer temperatures were not extremely high and the precipitation was nearly normal.

In Kansas the winter temperatures were much lower than in New Mexico. Chart No. 15 shows that the minimum for December was 10° F., for January 8° F., for February 3° F., and for March 20° F. The precipitation for December was 0.72 inch, for January 0.05 inch, for February 2.77 inches, and for March 0.86 inch. The minimum of 3° F. was recorded for February 1, and on the 19th and 20th the temperatures were 11° F. and 10° F. respectively. The

green bug increased in numbers throughout the dry months of December and January, but disappeared rapidly during the relatively wet month of February. Here we have a repetition of what is reported to have taken place in eastern Tennessee in March, 1890. But it will be recalled (chart No. 4) that the lowest temperature in that case was only 19° F. The lowest monthly mean in that case was 48° F., while in Kansas it was 33.5° F. for January and 34.5° F. for February.

It appears from this data: (1) That the green bug has successfully passed through the summer months and appeared in large numbers the following fall, winter and spring, when the monthly maximum summer temperatures have not exceeded 99° F., the monthly means have not exceeded 83° F., and the precipitation has been abundant. (Charts Nos. 2, 4, 6, 10, 12, 14, 15, 17.) (2) That following the destructive outbreaks of 1901 and 1906 they have failed to appear again in the fall or winter in noticeable numbers where the monthly maximum summer temperatures have ranged from 102° F. to 109° F. and the monthly means exceeded 83° F. and the precipitation has been deficient. (Charts Nos. 7, 9, 11 and 13.) (3) That they have successfully passed the winter months when the minimum temperature has not fallen below 10° F. and the monthly means have not fallen below 43° F. and the precipitation has been deficient. (Charts Nos. 2, 4, 6, 10 and 12.) In northeastern Kansas last winter they seemed to endure dry winter weather when the minimum temperature fell as low as 7° F. in January and the monthly mean as low as 33½° F. (Chart No. 15.) (4) That though present in the fall and winter they failed to survive in one case (chart No. 15) a moderately wet February, whose minimum was 3° F. and whose monthly mean was about 34° F.; and in another case a wet March (chart No. 4), whose minimum was 18° F. and whose monthly mean was 48° F. (5) That in the case of the outbreak of 1890 the spring weather was about normal, but in the case of the outbreaks of 1901 and 1907 the temperature for April and May was below normal. In the first case these were very wet months, and in the latter in some places they were wet and in others they were dry.

The above data are too meager and inaccurate to warrant us in drawing definite conclusions. I have used the temperatures given for the places and years mentioned in order to have definite data; but while they represent the general character of the climatic conditions of the regions within which they are located, their temperatures will necessarily vary some from those of other places within

the infested regions; so that while the data are definite for the given localities they must be considered as only approximate for the whole section concerned.

In order to obtain definite data, from which definite and final conclusions can be drawn, they must be obtained by trained observers in the field where the green bug actually exists. The data in regard to precipitation, relative humidity and winds must be for the field and the observations be secured for all possible climatic conditions.

These data, however, enable us to draw some general conclusions which, though in some respects may need revision, in the main will be found to be correct.

From facts brought out in this study of the climatic conditions of the years in which destructive outbreaks have occurred it appears that cool moist summers, mild dry winters and cool wet springs are the principal favorable conditions.

SUMMER CONDITIONS.

A destructive outbreak has never occurred, so far as reported, after a hot summer. The summers following the last two destructive outbreaks have been hot and generally dry, at least during some periods of the summer. This indicates that hot weather is unfavorable and even fatal to the green bug.

There are various reasons for the disappearance of the green bug in the heated season. They may be enumerated as follows: (1) The activity of the parasite and predaceous insects; (2) the necessity of the change of food-plant; (3) the scarcity of suitable food-plants; (4) the fatal effects of high temperatures on the green bug.

If the parasite is present at all, it multiplies so rapidly in warm weather that it soon gains the ascendancy over them, but it is very doubtful if it ever exterminates them. Those that escape must seek new food-plants as soon as the grains mature and become unsuitable for food. The winged ones take flight, but their flight is apparently aimless, and they are as apt to alight in the street of a village as in a locality where suitable food may be found. Hence, probably only a very small per cent. of those that take flight succeed in finding food. Those that are wingless, being unable to travel far to seek suitable food-plants, perish, unless on account of rains suitable food-plants are at hand.

Again, during hot summers, especially if dry weather prevail, suitable food is very scarce and many are thus starved to death.

Last November they were discovered in five different fields in Jefferson and Leavenworth counties, Kansas. Inspection of these fields revealed the fact that the origin of the outbreak in each case was in parts of the fields which were most protected from the sun's rays, although the food supply seemed equally good in other parts of the field. The origin of the outbreaks was on north slopes in four of these fields. South slopes were almost free, even in December. In one case they were abundant on a west slope near the edge of a field protected on the west by timber. It appeared as if they had been killed out in the exposed parts of the field.

I conducted several experiments to test the effect of heat on the green bug. For this purpose I used a breeding-cage heated by electric light during the daytime. I observed that when the temperature rose above 90° F. they began to get restless, and the more so as the temperature rose. They would cease feeding and run actively up and down the blades of wheat, leave the plant and seek to escape. It was difficult to keep them confined. In fact, in most of the experiments started they succeeded in escaping, or at least they disappeared and could not be found, dead or alive.

In one of these experiments I placed twelve adult wingless green bugs in the cage May 2. The daily maximum temperature in the cage ranged from 99° F. to 103° F., and the daily minimum from 52° F. to 67° F. By May 11 four of the adults were dead and there were about seventy-five young on the plant. On May 12 the maximum ran up to 107° F., and as a result I removed fifty-five dead bugs, found three bugs still alive, and the others were missing. In other experiments performed I found the fatality very high. In all these experiments the plants were watered daily.

While these experiments performed under these artificial conditions are by no means conclusive, still they lend to the belief that temperatures of 100° F. and over will kill the green bugs.

This view is further strengthened by the fact that other aphids likewise disappear in hot summer weather. Those which are not attacked by parasites disappear as well as those which are. Last spring, 1907, *C. negundinis* was abundant on box-elder, and in this section nearly defoliated the trees. I examined them frequently, but never found any evidences of parasitic enemies. Throughout July and August the casual observer would have said that they had disappeared completely, but a careful examination of the under sides of the leaves revealed some very diminutive ones in the angles of the veins. They were not much larger than the

newly-born aphids, were inactive, and did not seem to increase in size throughout the summer months.

It is only in localities where the temperature rises to 100° F. or above that they disappear. In Minnesota they were present throughout the summer months, but in no place in the state was there a record of a maximum as high as 100° F.

WINTER CONDITIONS.

In severe winters the living forms perish and the bug is carried through the winter in the egg stage. In mild winters the living forms survive the winter and are present in the fields when spring opens, in more or less destructive numbers, depending upon the severity of the winter. It is difficult to place definitely the limit of their endurance. It seems that they can endure much lower temperature in dry weather than in wet weather. In Jefferson county, Kansas, last winter, they survived the months of December and January and seemed to increase in numbers when the mean for December was 36.5° F., the minimum 10° F., the precipitation 0.72 inch, and the mean for January was 33.5° F., the minimum 7° F., and the precipitation 0.05 inch; but rapidly disappeared in February, when the mean was 34.4° F., the minimum 3° F., and the precipitation 2.39 inches. The minimum of 3° F., was recorded for February 1. On February 7 and 8 I inspected the field and found about fifty per cent. of the bugs dead. Up to this time there had been very little precipitation. The fatality above noted must be assigned to the cold. On March 28 I again inspected the field, and after a search of two hours found but four live bugs.

On wheat growing about one of the mills in Lawrence, Kan., there were some green bugs last fall, but none could be found this spring until May 30. After a somewhat extended search on that date I found a single specimen. It would appear from this that a mean temperature of about 34° F., with the minimum not lower than about 3° F., is about the limit of their endurance in dry winters, and if their reported disappearance in March, 1890, in eastern Tennessee is correct, the limit of their endurance in wet weather is about 15 degrees higher.

When the monthly means range between 34° F. and 40° F. they cannot increase in numbers very rapidly; for in our field experiments last winter it was found that at a mean temperature of 35° F. the adults reproduce at the rate of about one in three days during the reproductive period, and it requires from seventy-five to ninety days for the young to mature. As soon as those which are adults

when cold weather approaches die, reproduction will practically cease until spring.

It would appear from this that in eastern Texas, where the lowest monthly normal is nearly 45° F., any green bugs present in the fall would have no difficulty in passing the winter; and it is probable that they do not. The most critical time for the green bug in Texas is the summer, and especially August, when the normal rainfall for northeastern Texas is only about 2.25 inches. Had they been present last fall in Texas there would without doubt have been another destructive outbreak there this spring, for reference to chart No. 11 will show that the lowest monthly mean for the winter was 48.5° F., and 20° F. was the lowest recorded temperature at Fort Worth.

When the monthly mean temperatures range between 50° F. and 60° F., as they did in Texas in the winters of 1890–'91, 1900–'01, and 1906–'07, the green bugs breed rapidly, and in the absence of parasites which are also active at these temperatures soon increase in numbers to such an extent as to become a destructive pest.

SPRING CONDITIONS.

Cool spring weather is favorable to the green bug in at least three ways: (1) The parasite is not so active in cool as in warm weather; (2) cool spring weather prevents the grains from maturing so rapidly and thus prolongs the season of suitable food supply, and (3) the green bug lives longer and produces a greater number of young in cool than in hot weather. In experiments carried on last summer, when the mean monthly temperatures were between 70° F. and 80° F., it was found that the average length of life of the green bug was 35.2 days, the average period of reproduction was 22.7 days, and the average number of young produced by each individual was 55.4, while this spring, when the mean monthly temperatures were between 50° F. and 60° F., the average length of life was 60.9 days, the average reproductive period was 38.7 days, and the average number of young produced by each individual was 57.8.

When the spring weather is warm the parasites are more active, the grain matures more rapidly, and the early approach of summer heat increases the fatality, so that they disappear rapidly.

In the spring of 1890 the temperature of the spring months was about normal and the green bug did not escape north as far as Kansas. In the spring of 1901 the temperature was slightly below normal and the green bug in its northern progress reached the

southern border of Kansas, but in the spring of 1907 the temperature for the spring months after March was many degrees below normal, and the green bug swept north to near the Canadian line, and covered nearly all the grain regions east of the Rocky Mountains.

WET AND DRY WEATHER.

I have repeatedly referred to precipitation in this discussion and need only to summarize by saying that in the hot season of the year dry weather is fatal to the green bug, because it reduces the available food supply and favors the parasite. At ordinary spring temperatures the green bug seems to prefer moderately dry weather. It avoids low, damp places; but wet weather does not seem to present any particular hindrance to it, and does hinder its principal parasite. So that, on the whole, wet spring weather is most favorable. At low temperatures wet weather is fatal to the green bug, as has already been shown.

CONDITIONS MOST FAVORABLE FOR RAPID REPRODUCTION.

As already stated, our experiments seem to show that at temperatures ranging from 50° F. to 60° F. the green bug lives longer and produces a greater number of young during its lifetime than at temperatures ranging from 70° F. to 80° F., but in the latter case the rate of reproduction per day for each individual during the reproductive period was greater than in the former case.

Which in the long run is the greater rate of reproduction is a problem for the mathematician to solve. But it is certain that the most favorable conditions are in the spring months after winter temperatures have ceased and before the high summer temperatures come.

CONCLUSION.

In conclusion, we may say that the green bug, aside from being at the mercy of its many natural enemies, has a very precarious existence on account of climatic conditions. It cannot endure the high temperatures which prevail in summer, or the low temperatures which prevail in winter in most of the grain-growing sections. For this reason it is confined to the temperate zone, and chiefly to those regions bordering on large bodies of water, where the great extremes in summer and winter do not occur, rather than to inland regions.

But it does manage to exist. However unfavorable the climatic conditions may be over a region in general, some local conditions somewhere will enable a few to survive here and there, and

when more favorable conditions come these will soon be able to restock the depleted section, and when a cool moist summer is followed by an exceptionally mild winter they will, in the absence or scarcity of their natural enemies, be able to appear in such numbers the following spring as to merit the descriptive title, "Destructive Outbreak."

II.—CLIMATIC CONDITIONS AND *L. tritici.*

In experiment No. 2 the adult parasites survived a temperature as low as 17° F. In the morning of December 20 the minimum temperature was 21° F.; that afternoon, at 2:30 P. M., when the temperature was 51° F., the parasites were observed to be active, seeking out and stinging bugs. When the temperature falls below 35° F. or 36° F. the adults become inactive, and remain motionless on the blade of wheat or on some other object. They remain thus until the temperature falls to the minimum limit of their endurance, which is about 17° F., and then fall to the ground dead, or until the temperature rises to 35° F. or above, when they become active again. From 35° F. to 40° F. they are only feebly active, but have been observed to sting bugs at 38° F. and 40° F., and to try to sting bugs at 35° F. in a very feeble way, but apparently without success.

As the temperature rises above 45° F. their activity increases, and appears to be about normal at 70° F. At temperatures higher than that they show a greater tendency to take flight and a less tendency to seek for bugs for the purpose of stinging them.

Their normal method of passing the winter is in the pupa state, and they can probably survive very severe winters. Those that are in the larva state when cold weather sets in continue to develop so long as the temperature does not get low enough to kill the green bug. Last winter, 1907-'08, so long as we found green bugs in the field we found parasitized bugs that were turning yellow. As soon as the host perishes the larva dies, and only those that are in the pupa state survive. Adult parasites were seen in the field on February 7 last winter, showing that the pupa develops and the adult emerges at quite low temperatures: viz., when the extremes range between 60° F. and 3° F., and the mean is about 35° F.

The development period of the parasite is influenced greatly by temperature. From sixty-one experiments the following results were obtained. The development period at 35° F. is from 114 to 140 days; from 55° F. to 60° F., 23.4 days; from 60° F. to 65° F., 16.06 days; from 65° F. to 70° F., 13.07 days; from 70° F. to 72°

F., 11 days. In these experiments the minimum time noted was 7 days.

In rainy weather the parasite is inactive and seeks shelter. In several experiments performed in the field in June, 1908, when hardly a day passed without rain, not a single green bug was parasitized. A few days later, after the rains had ceased, a single parasite placed with green bugs was active for five days and parasitized ninety green bugs.

When the mean temperature falls below 55° F. the parasites do not multiply rapidly, because it requires nearly a month or even more, for them to develop. In the spring they are usually scarce, especially in the latitude of Kansas, because the winters are usually severe enough to kill the green bugs; hence all those that are in the larva stage when severe weather approaches perish and only those which have reached the pupa stage survive. They increase in numbers in the spring as the temperature rises and the period required for development decreases. The time of their greatest abundance in Kansas in 1907 was in May. During the hot months of July and August they decrease in numbers because of a lack of hosts, since the green bugs cannot endure temperatures much above 100° F.

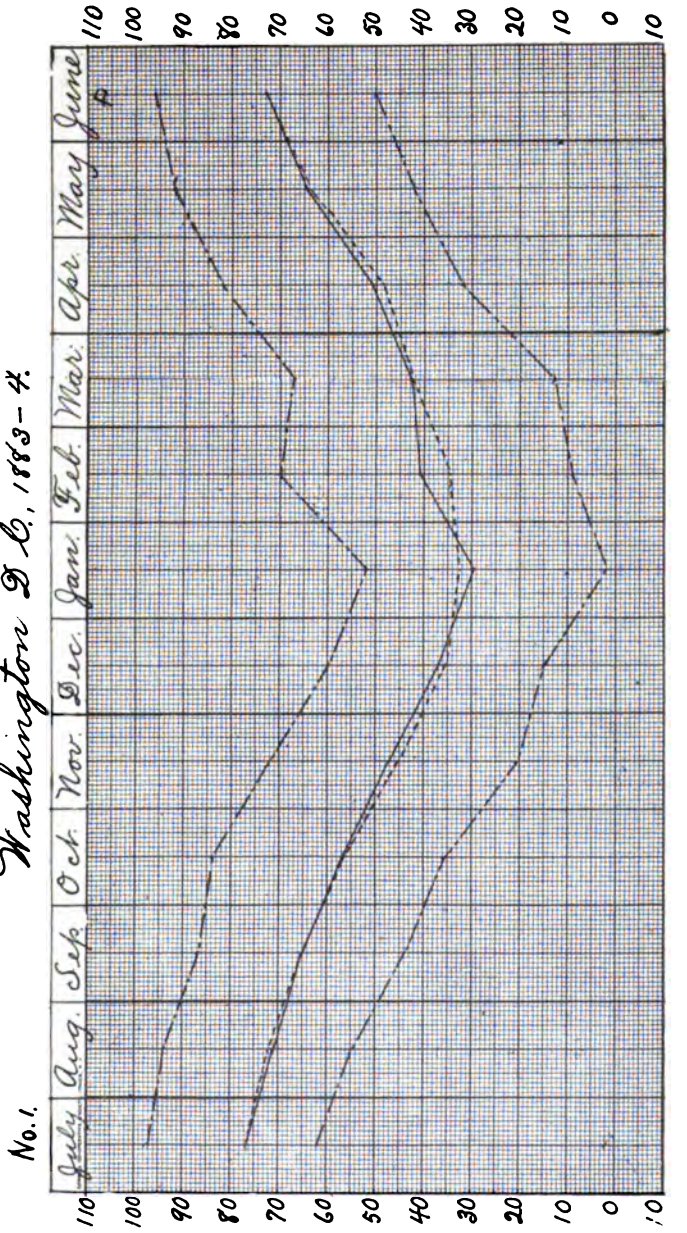

No. 1.
Washington D. C., 1883-4.
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10

FIGURE 49.

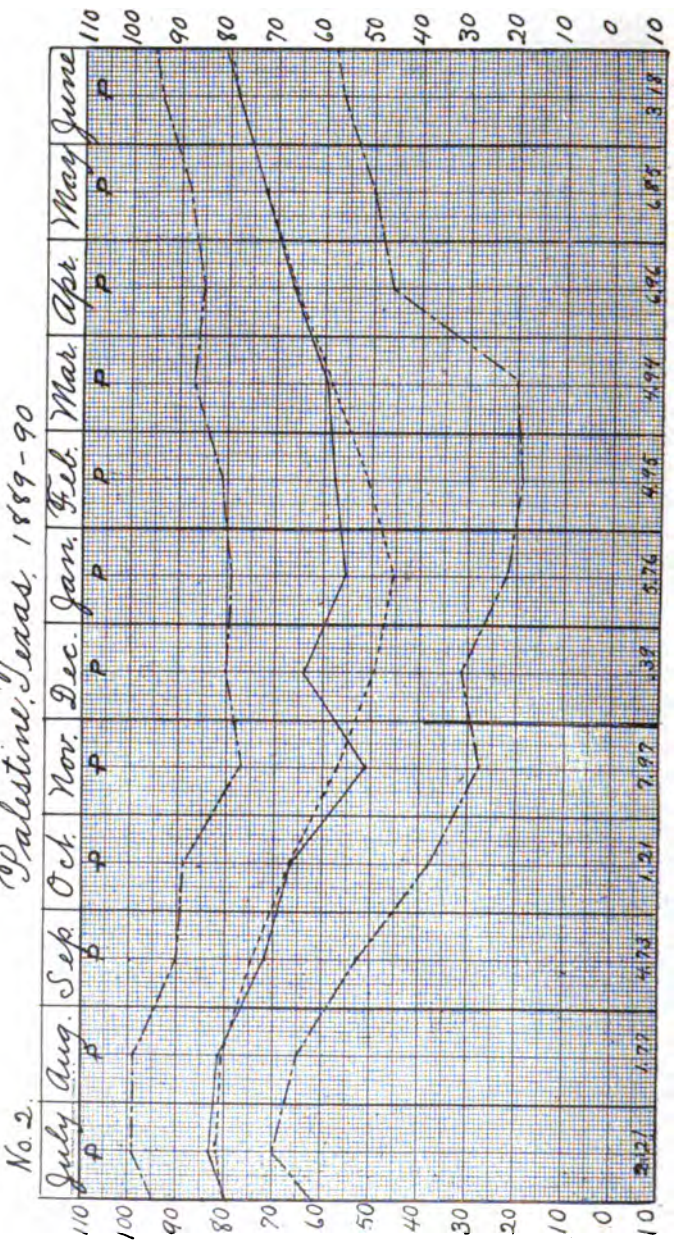

No. 2.
Palestine, Texas, 1889-90
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
P
110
100
90
80
70
60
50
40
30
20
10
0
10
3.18
4.85
4.92
4.91
4.96
5.74
.39
2.97
1.21
4.73
1.72

FIGURE 50.

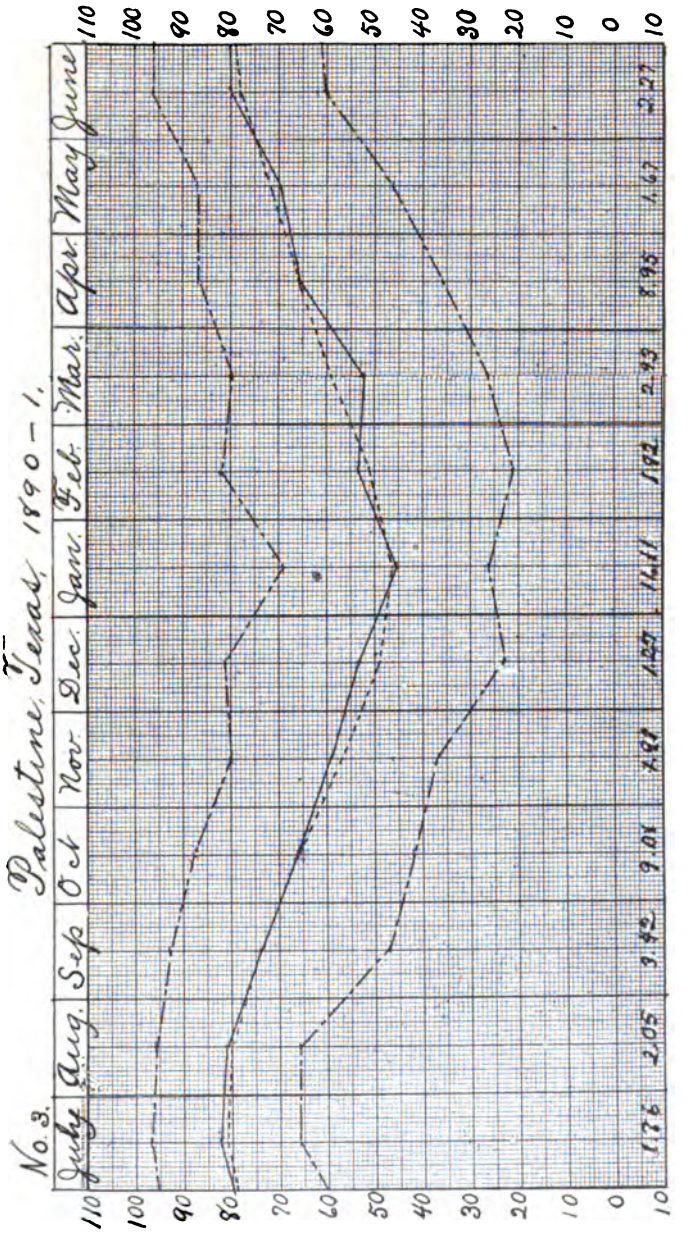

No. 3.
Palestine, Texas, 1890–1.
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
1.26
2.05
3.42
9.01
4.81
1.29
14.11
1.92
2.93
8.93
1.42
2.27

FIGURE 51.

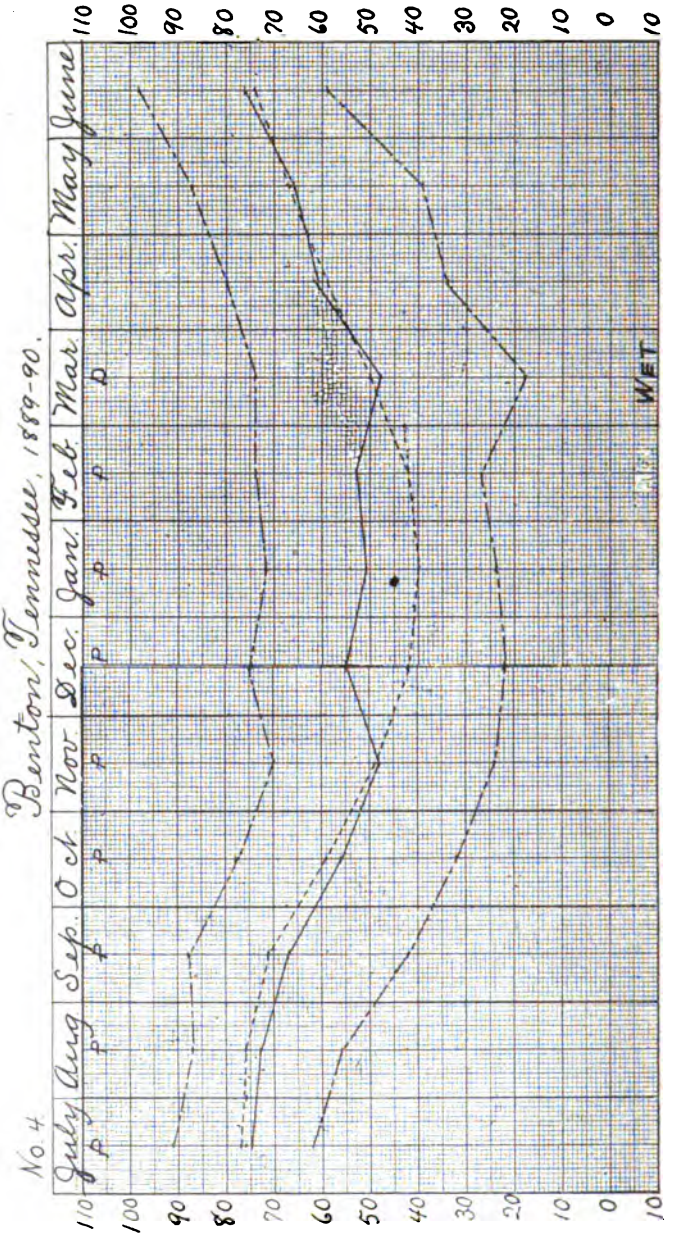

No. 4.
Benton, Tennessee, 1889-90.
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
WET
110
100
90
80
70
60
50
40
30
20
10
0

FIGURE 82.

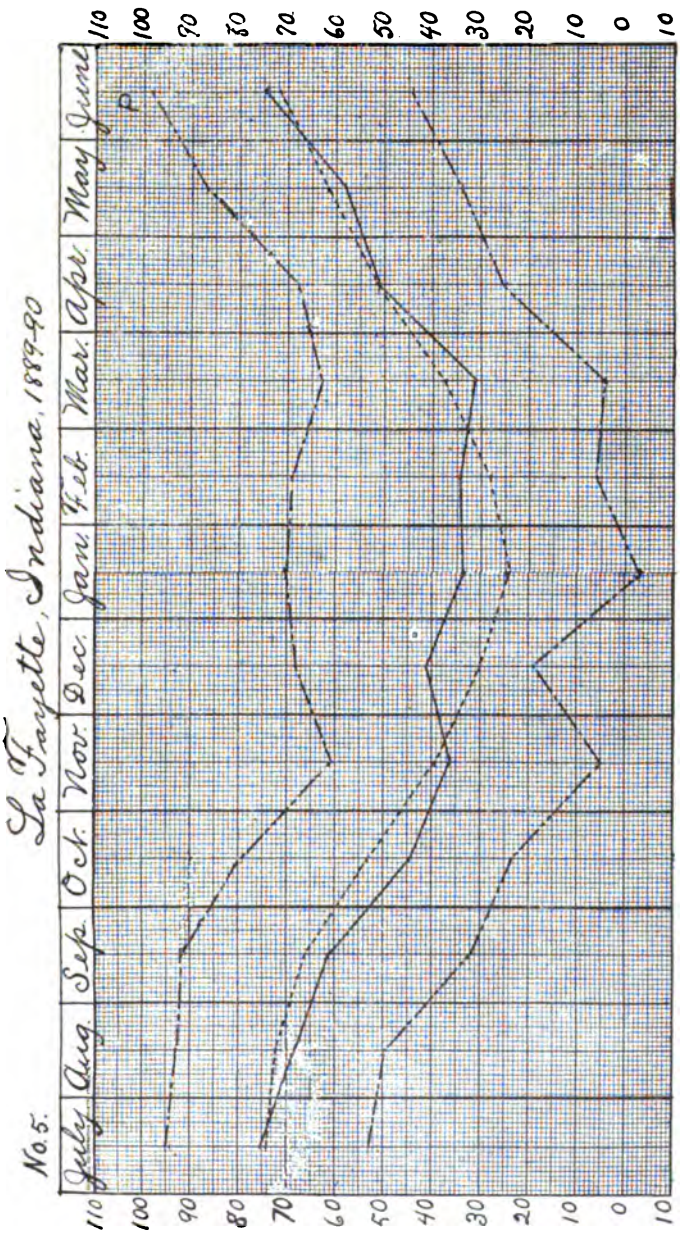

No. 5.
La Fayette, Indiana, 1889-90
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10

FIGURE 53.

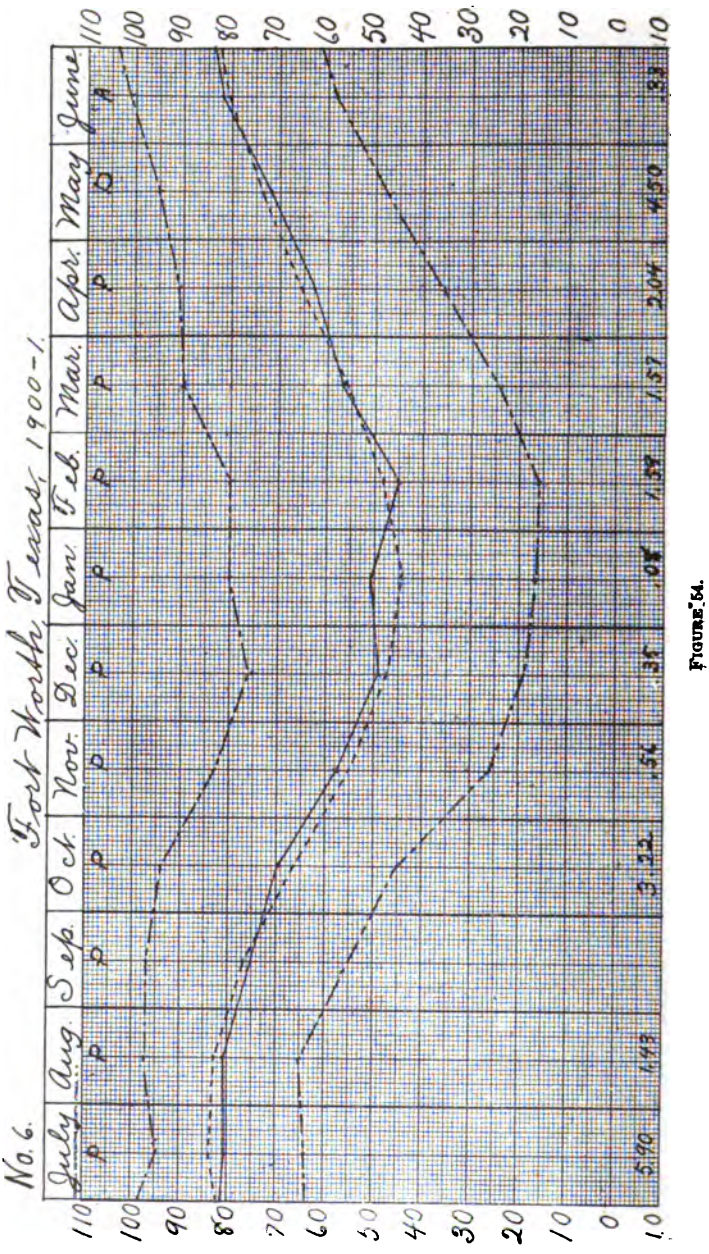

No. 6.
Fort Worth, Texas, 1900-1.
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
P
D
5.90
1.93
3.22
.54
.35
.08
1.89
1.57
2.04
4.90
8.9

FIGURE 54.

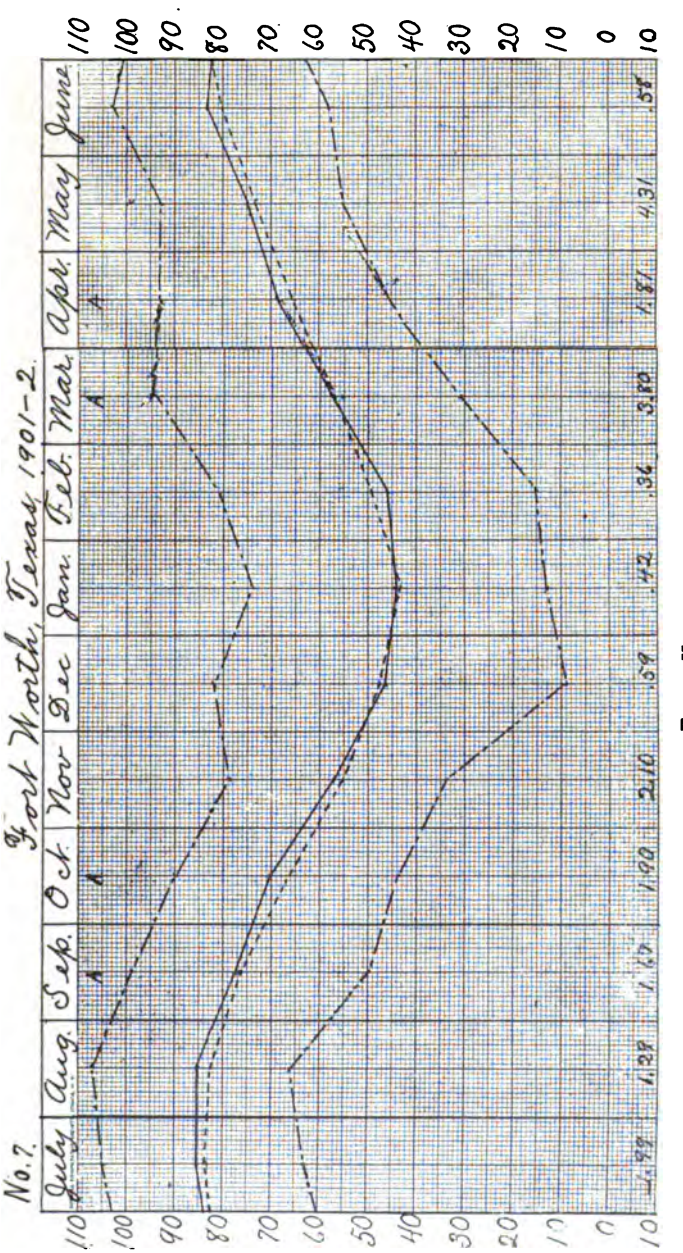

No. 7.
Fort Worth, Texas, 1901–2.
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
1.88
1.28
1.10
1.90
2.10
1.09
1.42
1.96
3.80
4.81
4.31
5.8

FIGURE 55.

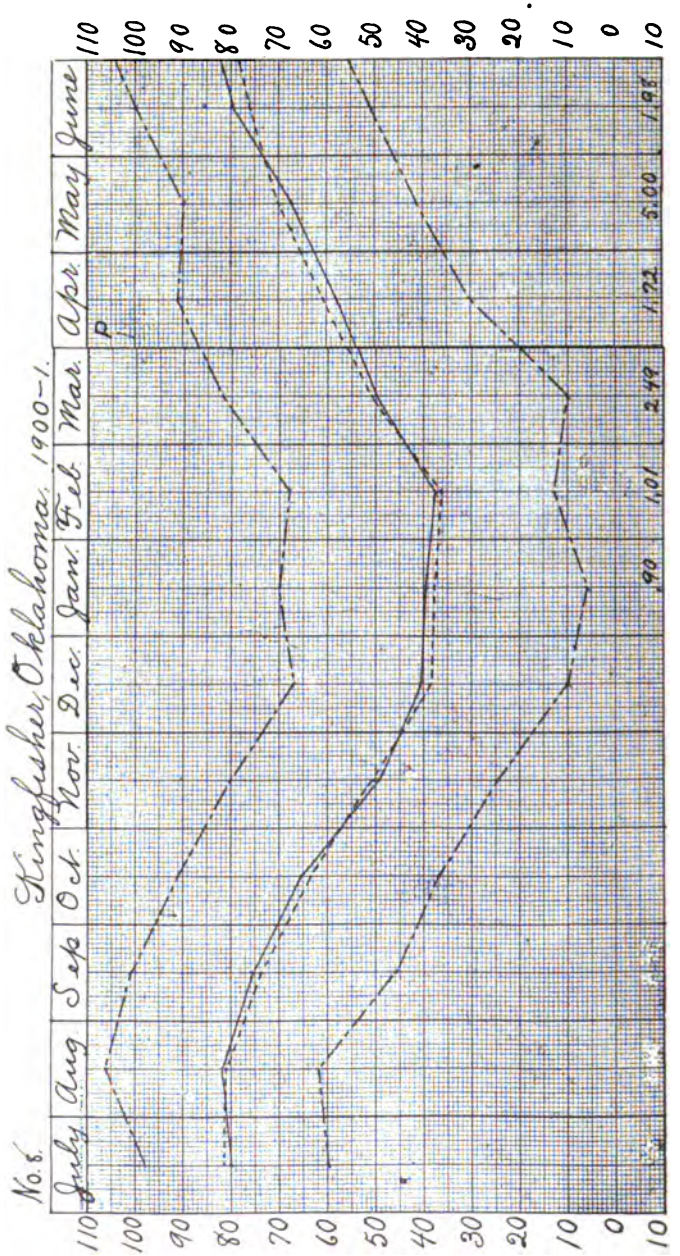

No. 5.
Kingfisher, Oklahoma, 1900-1.
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
.90
1.01
2.49
1.22
5.00
1.98

FIGURE 56.

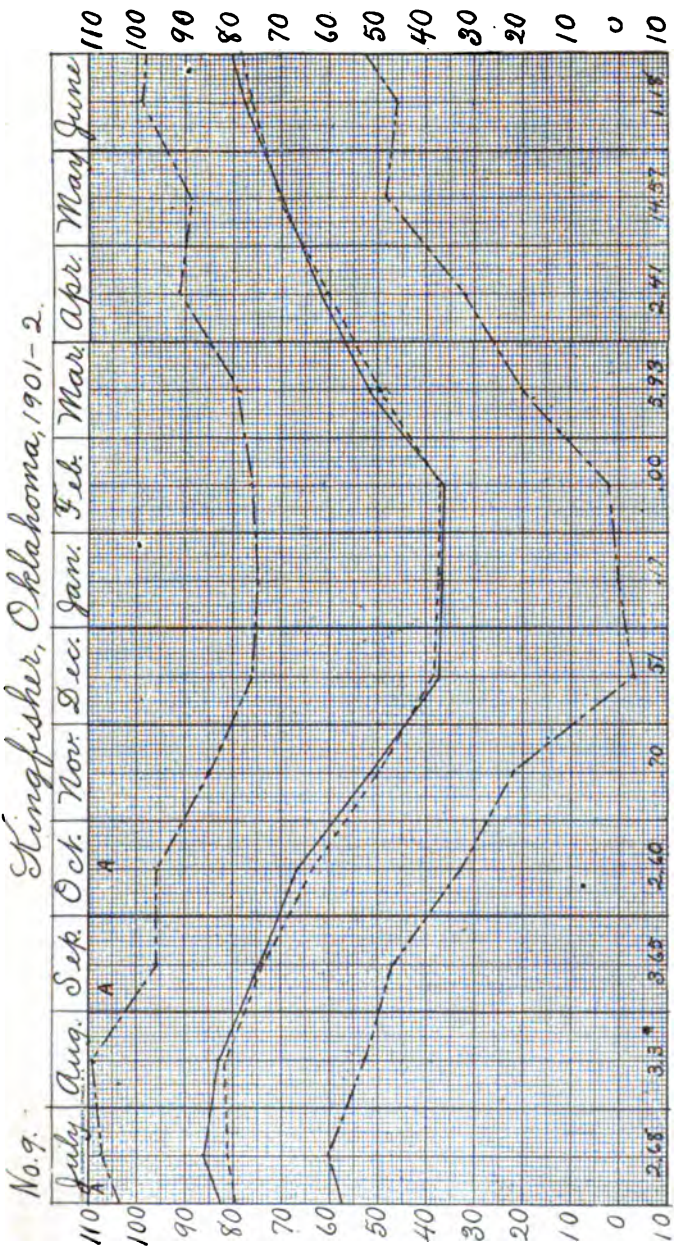

No. 9.
Kingfisher, Oklahoma, 1901–2.
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
2.68
3.33
3.65
2.60
.70
.57
1.00
5.93
2.41
1.48

FIGURE 57.

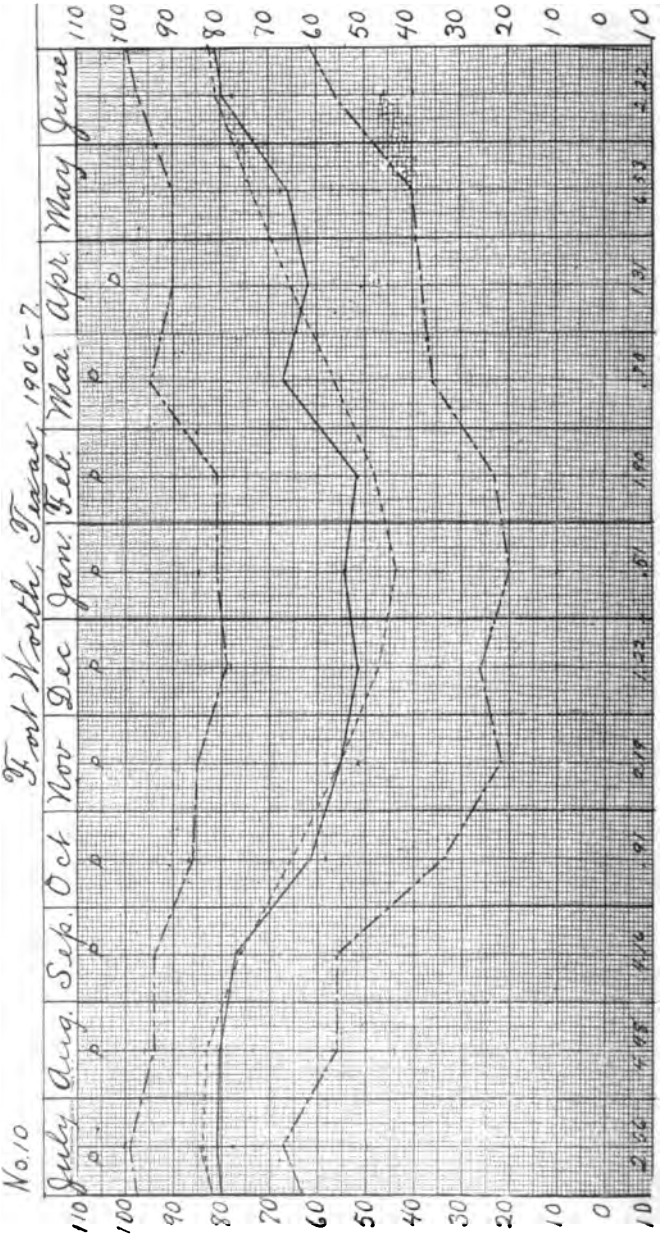

No. 10
Fort Worth, Texas 1906-7
July
Aug.
Sep.
Oct.
Nov.
Dec
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10

FIGURE 82.

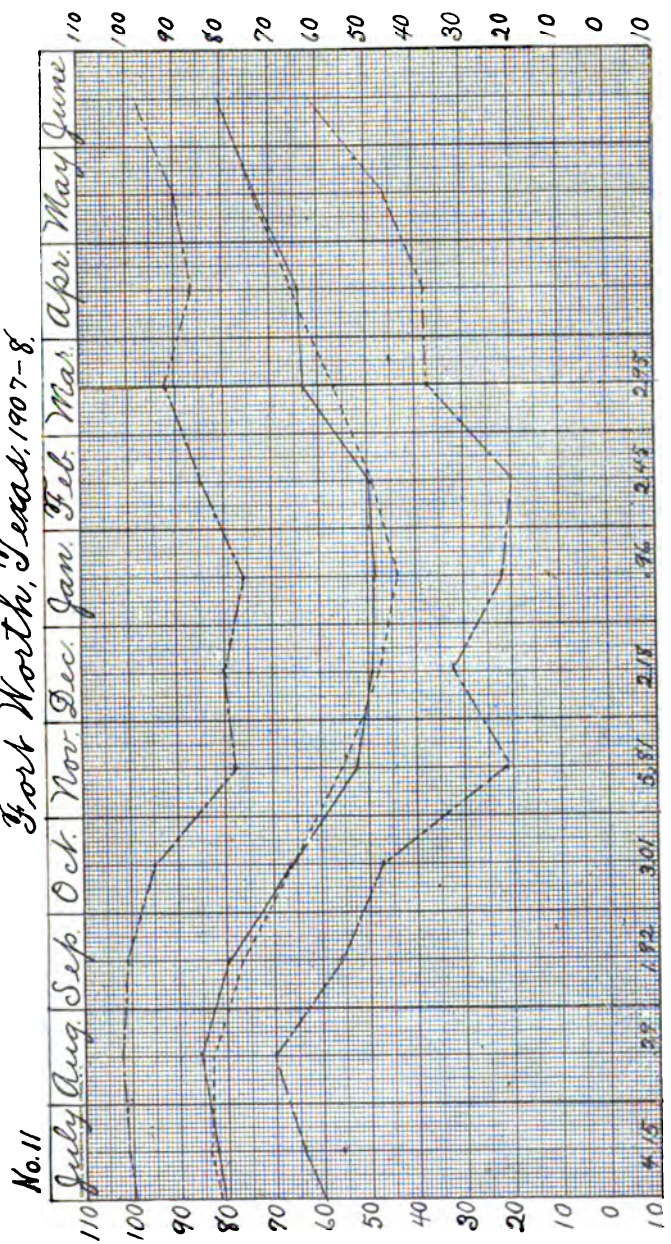

No. 11
Fort Worth, Texas; 1907-8.
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
4.15
2.2
1.82
3.01
5.81
2.18
.94
3.48
2.95

FIGURE 59.

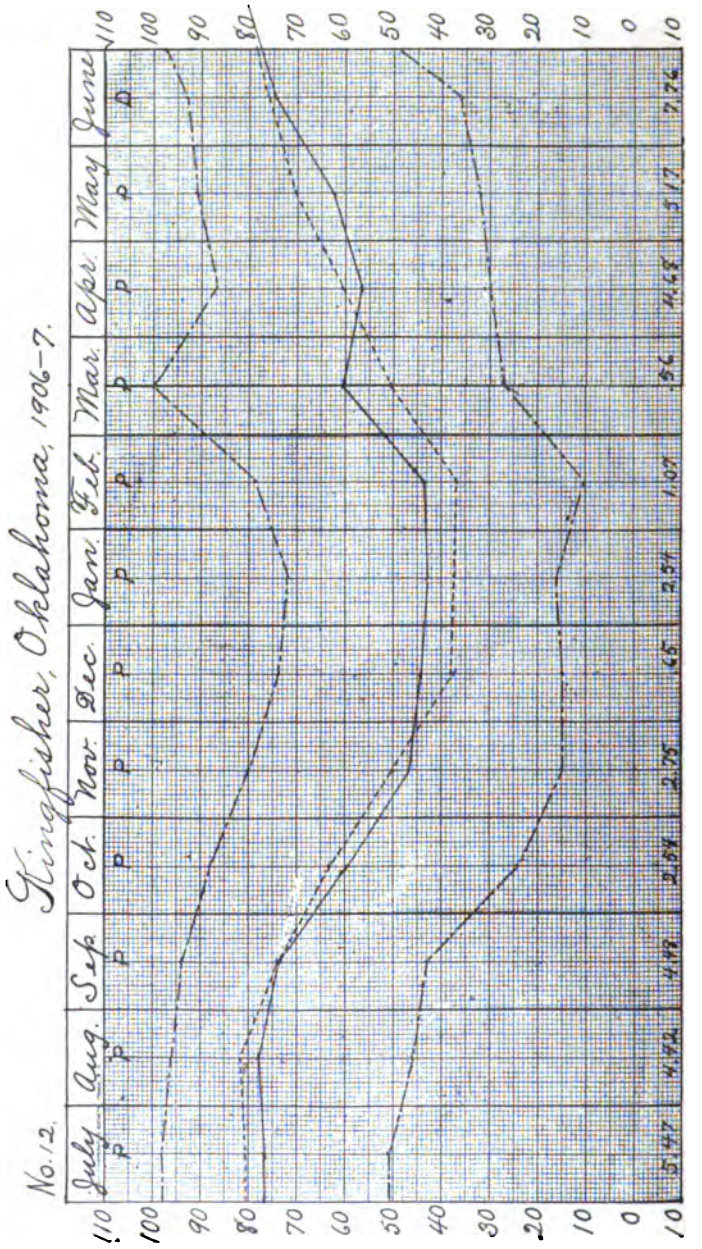

No. 12.
Kingfisher, Oklahoma, 1906-7.
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10

FIGURE 60.

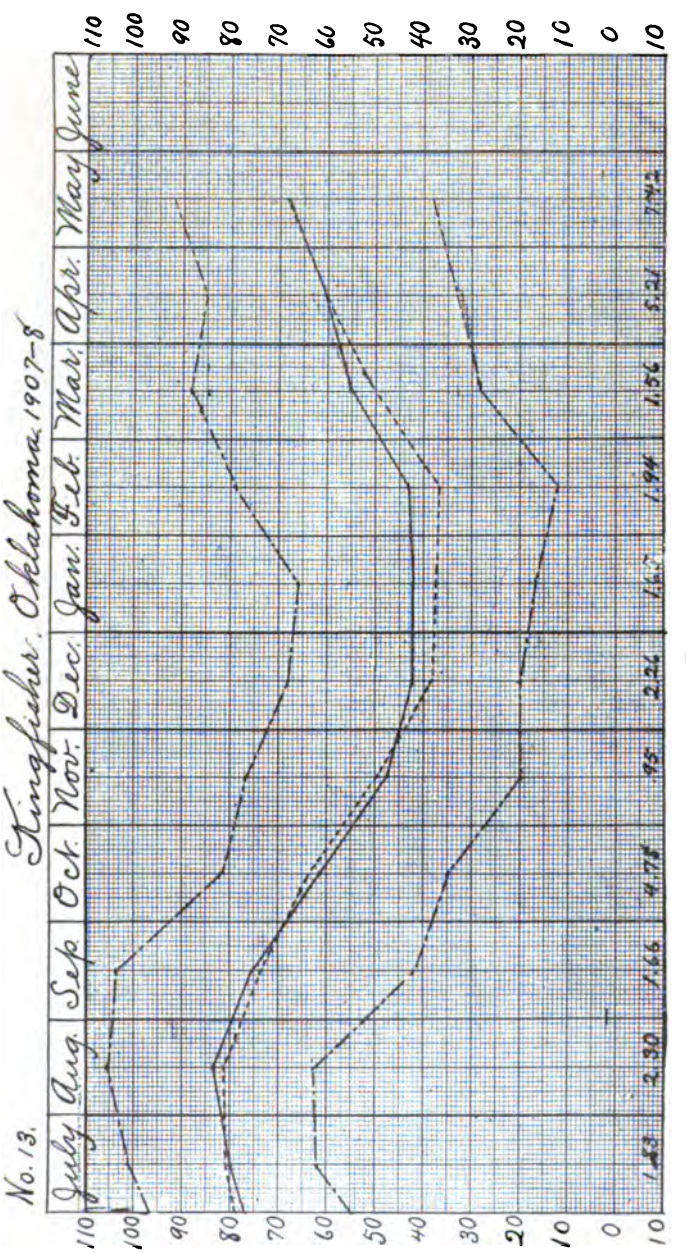

No. 13.
Kingfisher, Oklahoma, 1907-8
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
1.83
2.30
1.66
4.78
.95
2.26
1.94
1.56
5.21
7.42

FIGURE 61.

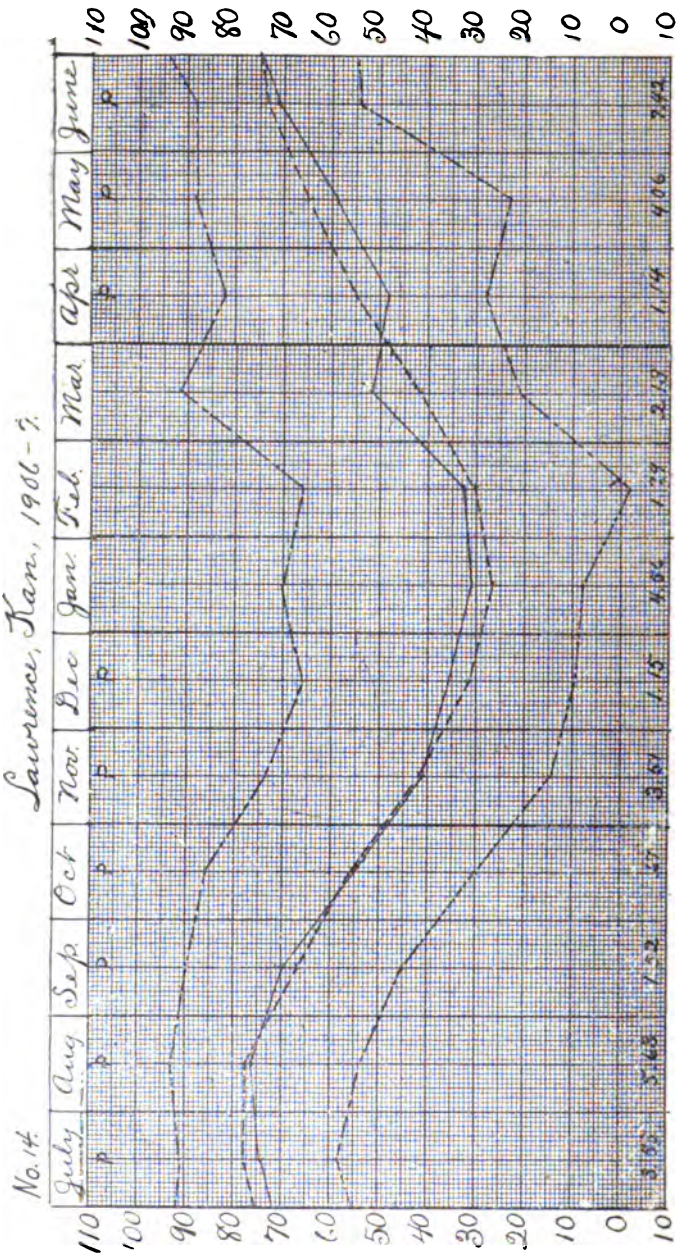

No. 14
Lawrence, Kan., 1906-7.
July
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
P
3.95
3.68
1.52
3.61
1.15
4.86
1.29
2.13
1.14
4.06
2.62

FIGURE 62.

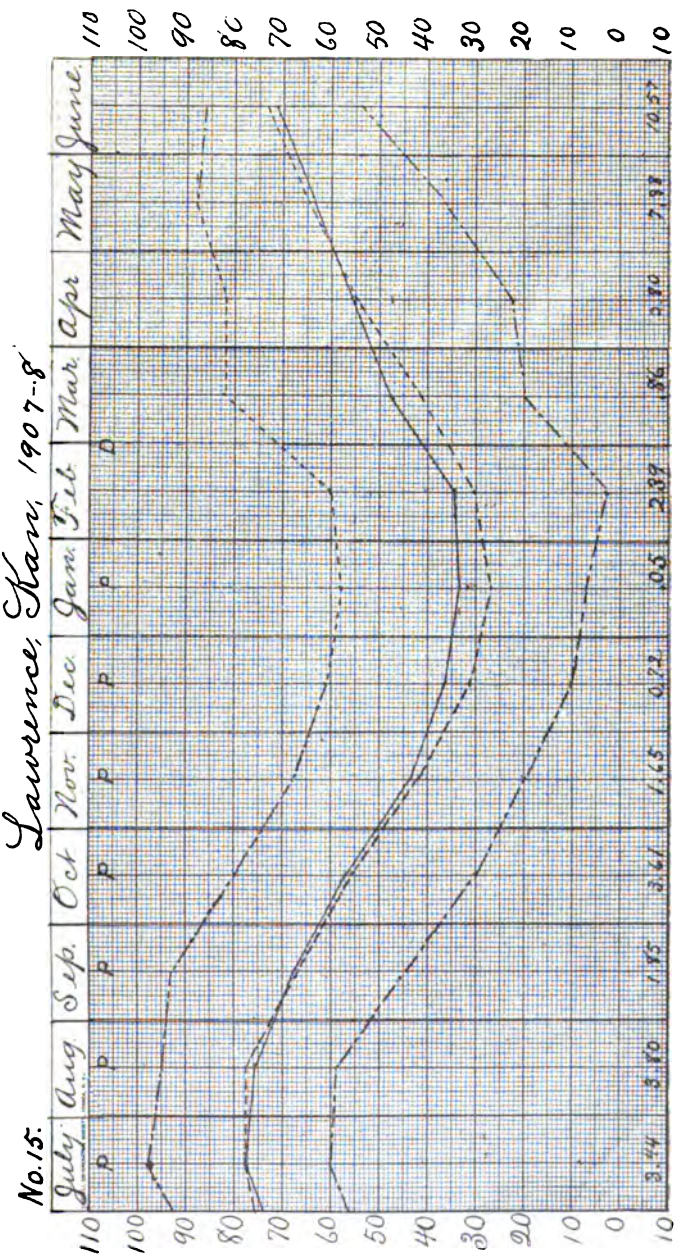

No. 15.
Lawrence, Kan., 1907-8
July
Aug.
Sep.
Oct
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June.
110
100
90
80
70
60
50
40
30
20
10
0
10

FIGURE 68.

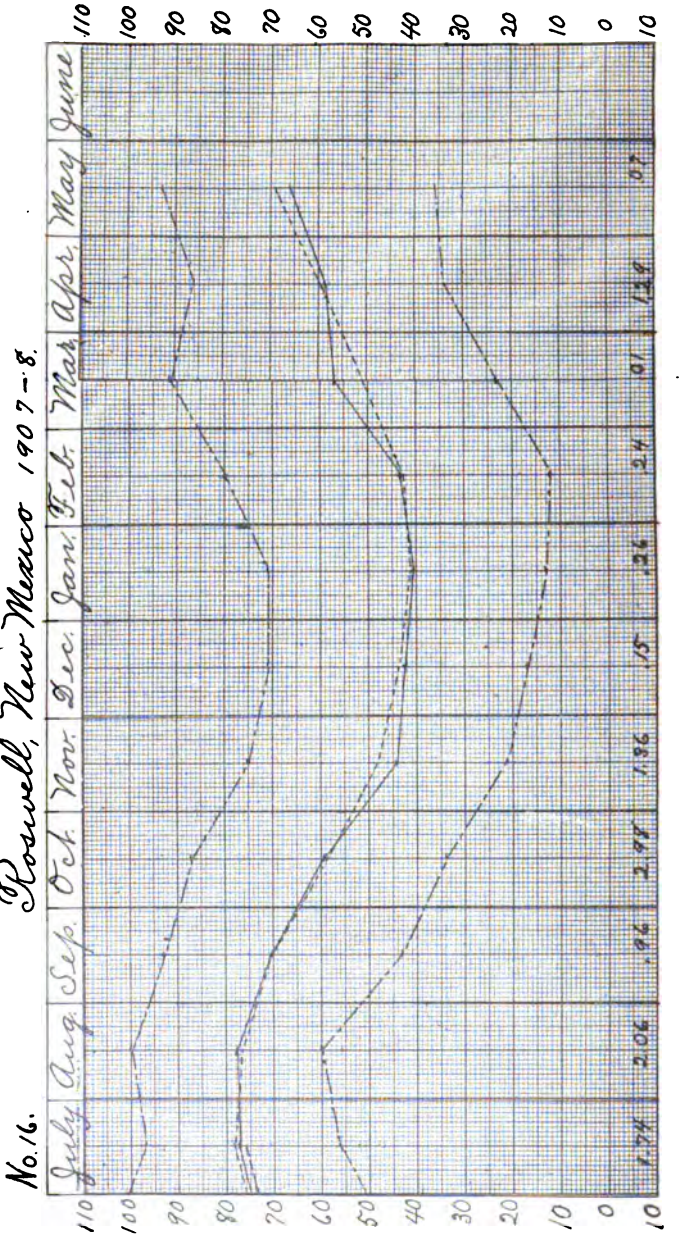

No. 16.
Roswell, New Mexico 1907-8.
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mch.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
1.74
2.06
.96
2.95
1.86
.15
.26
.24
.61
1.28
.07

FIGURE 64.

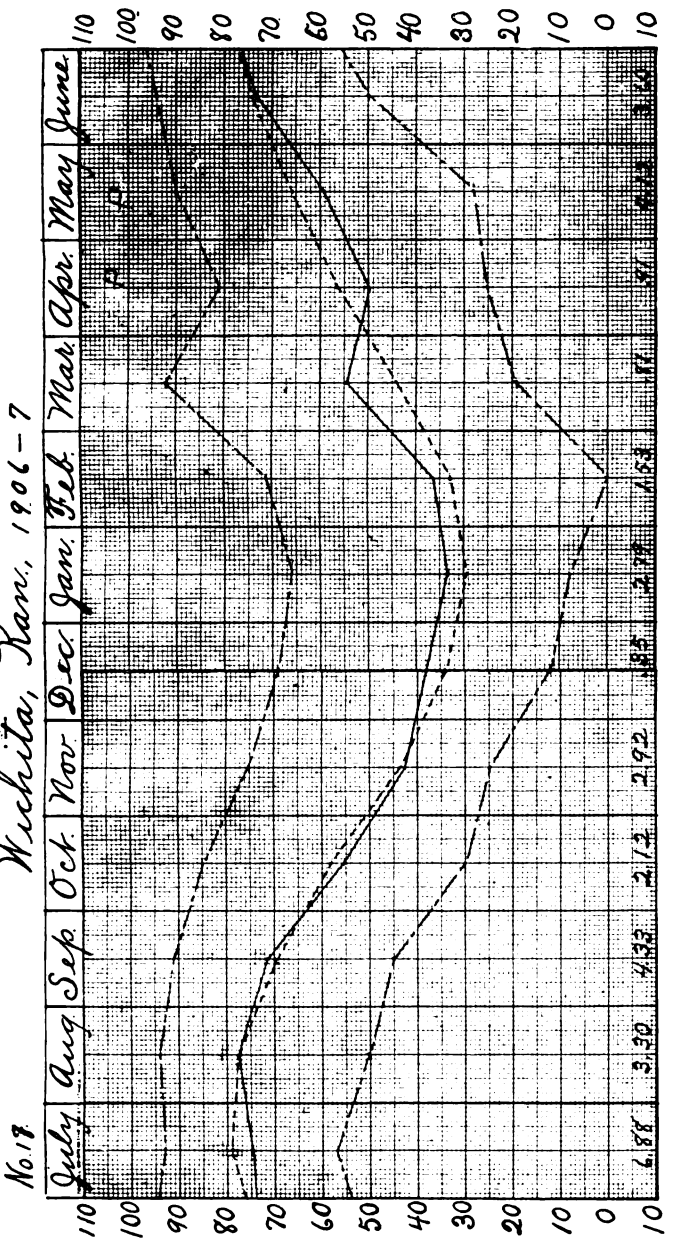

No. 18
Wichita, Kans., 1906–7
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
P
T
6.88
3.30
4.32
2.12
2.92
3.78
1.63
3.20

FIGURE 65.

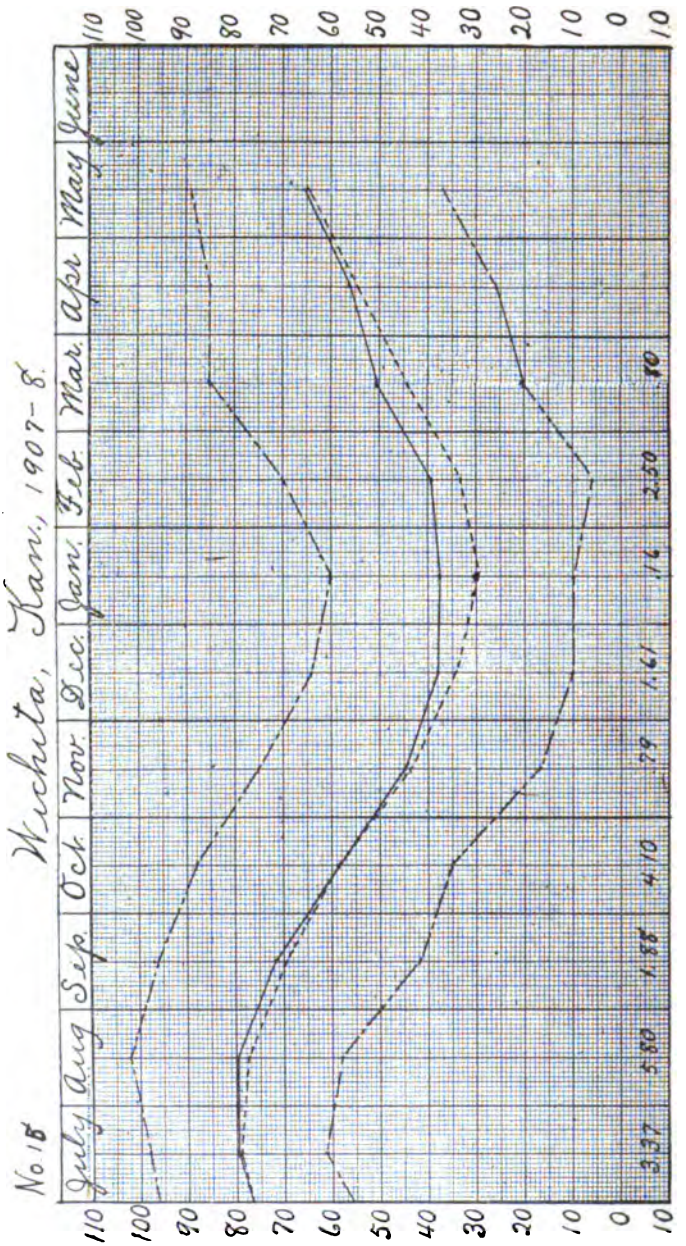

No 15
Wichita, Kan., 1907-8.
July
Aug
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr
May
June
110
100
90
80
70
60
50
40
30
20
10
0
10
337
580
1,88
410
99
1,67
116
250
10

FIGURE 66.

FINANCIAL REPORT.

Report of the finance committee, giving itemized statement of receipts and disbursements on account of extermination of green bug:

RECEIPTS.

From state funds			$150 00
Contributions from milling companies and grain men to further the work, as follows:			
Bowersock Milling Co. (contribution $100; returned $90)		$100 00	
Kansas City Millers' Club		25 00	
Kansas City Board of Trade:			
Broadnax & McLiney	$10 00		
Goffe & Carkener	10 00		
Thresher & Fuller	5 00		
Terminal Elevators	10 00		
Murphy Grain Co	10 00		
A. C. Davis & Co	5 00		
W. W. Cowen	5 00		
Carrington, Patten & Co	5 00		
Simonds-Shield Grain Co	10 00		
Nash-Ferguson Grain Co	5 00		
Southern Grain Co	5 00		
John I. Glover	5 00		
W. T. Kemper Elevator Co	5 00		
Geo. A. Adams Grain Co	5 00		
Allen Logan	5 00		
S. A. Dayton Grain Co	5 00		
Hall-Baker Grain Co	10 00		
B. C. Christopher & Co	10 00		
E. D. Bigelow	3 00	128 00.	
Topeka millers:			
Thos. Page	$10 00		
Hackney & Co	5 00		
Shawnee Mill Co	5 00		
Willis Norton & Co	10 00		
Crosby Rolling Mill	10 00	40 00	
Rea-Patterson Milling Co., Coffeyville		10 00	
New Era Milling Co., Arkansas City		10 00	
Winfield Roller Mills, Winfield		10 00	
E. J. Smiley, secretary Kansas Grain Dealers' Association, Topeka		25 00	
Ellinwood Mill and Elevator Co., Ellinwood		10 00	
Bemis Bros. Bag Co., Kansas City		25 00	
Kansas Mill and Exp. Co., Kansas City		10 00	
N. W. Miller, Kansas City		10 00	
Central Flour Co., Kansas City		5 00	
Grant Milling Co., Larned		10 00	
Samuel Rothweiler, Bison		2 00	
Concordia Mill Co., Concordia		5 00	
Excelsior Water Mill, Burlington		5 00	
G. Barkemeyer, Sedgwick		5 00	
Eagle Mill Co., Newton		10 00	
Walnut Creek Milling Co., Great Bend		25 00	
Lee-Warren, Salina		10 00	
H. J. Arnold, Sterling		5 00	

Contributions from milling companies—*continued:*		
Kansas City Bag Manufacturing Co., Kansas City	$15 00	
Imboden Milling Co., Wichita	5 00	
Howard Mills, Wichita	10 00	
Zenith Milling Co., Kansas City	10 00	
Halstead Mill and Elevator Co., Halstead	5 00	
H. D. Lee Mercantile Co., Salina	10 00	
Snell Mill and Grocery Co., Clay Center	5 00	
Jackman Roller Mills, Minneapolis	7 50	
Minneapolis Mill and Elevator Co., Minneapolis	7 50	
Farmers' Elevator Co., Minneapolis	5 00	
John Bartley, Minneapolis	5 00	
Willis Norton & Co., Topeka	10 00	
Ismet-Hinkle Mill Co., Kansas City	10 00	
Arms & Kidder, Kansas City	10 00	
Tyler & Co., Junction City	2 50	
Forsha Milling Co., Forsha	5 00	
J. R. Soden, Emporia	5 00	
Kansas Milling Co., Wichita	10 00	
E. R. & D. C. Kolp, grain dealers, Wichita	10 00	
J. B. Ward and W. H. Fluke, Gardner	2 00	
D. R. Krehbiel, secretary and manager Moundridge Milling Co	2 00	
J. J. Decker	1 00	
August J. Bulte	10 00	
New Era Milling Co	10 00	
Geo. F. Fernie, Hutchinson	5 00	
		662 50
Contributions and amounts paid in for parasites as follows:		
Hoffman Mill and Elevator Co., Enterprise	$1 00	
Hoffman Mill and Elevator Co., Navarre	1 00	
T. W. Lemmon, Stafford	2 00	
Kramer Milling Co., Anthony	10 00	
Larabee Flour Mills Co., Stafford	10 00	
T. Barber, Miltonvale	1 00	
A. W. Spickard, Turon	1 00	
Ralph M. Rudd, Belpre	1 00	
Ellsworth Mill and Elevator Co., Ellsworth	10 00	
C. A. Schmidt, Freeport	10 00	
D. J. Fair Lumber Co., Sterling	10 00	
M. Bishop, Topeka	1 00	
D. F. Kuns, President McPherson Bank, McPherson,	1 00	
J. W. Moore, Canton	1 00	
Robert Law, Anthony	1 00	
Clark Conkling, publisher Lyons *Republican*, Lyons,	1 00	
R. W. Thompson, cashier First National Bank, St. John	1 00	
Cairo Mills and Elevator Co., Cairo	10 00	
T. B. Sweet, Lawrence	1 00	
W. A. Nye, Downs	10 00	
Logan & Lewis, Pawnee Rock	1 00	
H. L. Kunce, secretary and manager Hiawatha Milling Co., Hiawatha	20 00	
Garfield Coöperative Association, Garfield	25 00	
D. M. Brower, Lewis	1 00	
J. E. Dickinson, Burlington	1 00	
Chas. McMurray, Turon Telephone Co., Turon	15 00	
R. O. Minor, Cottonwood Falls Mill and Elevator Co., Cottonwood Falls	5 00	
R. W. Thompson, cashier First National Bank, St. John	11 00	
Chas. Hayden, Holton	4 00	
Lindas Lumber Co., Larned	5 00	

Contributions—*continued:*

O. W. Dawson, contributions Commercial Club, Great Bend	$10 00
Hoisington Mill and Elevator Co., Hoisington	5 00
Solt Bros., Barnes	2 00
J. Q. Banta, proprietor Oberlin Roller Mills, Oberlin,	5 00
J. C. Leach, Carbondale	5 00
Wm. McCotton, Cherryvale	1 00
Paxico Mill Co., Paxico	5 00
Turon Milling Co., (Chas. McMurray), Turon	5 00
F. L. Williamson, Clay Center	10 00
Newton Mill and Elevator Co., Newton	5 00
Kansas Grain Co., Hutchinson	110 00
J. H. Britner, Shields	3 00
P. E. Howe, Peabody	2 00
C. F. Peterson, Parker	1 00
Bosse & Brodie, Ellinwood	5 00
Humburg Lumber Co., Bison	5 00
J. & R. Garvin, Stafford	5 00
Corenie Collins, Barnes	1 00
R. T. Williams, Hiattville	1 00
W. E. Bentley, Catalpa	1 00
M. H. Yoder, Conway	3 00
Edw. Berg, McPherson	1 00
Pratt Mill and Elevator Co., Pratt	5 00
C. F. Beery, Paola	2 00
Rock Island Mill Co., Hutchinson	10 00
John G. Sears, Calista	1 00
Alex. M. McBurney, Halstead	1 50
Robert Ward, cashier Farmers and Merchants Bank, Webster	3 00
J. H. Bosse, Ellinwood	5 00
D. M. Rothweiler, cashier, Bison	10 00
C. Wood Davis, Viola	1 00
C. Hoffman Milling Co., Enterprise	10 00
Claflin Grain and Fuel Co., Claflin	50 00
Humburg Lumber Co., Bison	2 50
M. Haynes, cashier Pawnee Rock State Bank, Pawnee Rock	1 00
J. A. Bergland, Larned	2 00
S. M. Law, Canton	1 00
W. G. Martin, Eskridge	2 00
H. A Coombs, Healy	1 00
H. S. Jennison, cashier First State Bank, Healy	1 00
H. B. Smith, Larned	1 00
W. B. Anderson, Brownell	1 00
C. S. Gauner, Lawrence	1 00
F. D. Broadbent, Erie	1 00
R. Hampson, Hillsdale	3 00
R. A. Sankey, Wichita	1 00
Hiawatha Milling Co., Hiawatha	20 00
Samuel Brybread, Elk City	1 00
Farmers' Grain, Fuel and Live Stock Co., Pawnee Rock	1 00
Samuel C. Groth, Ellsworth	3 00
D. P. Lindsay, McPherson	1 00
G. W. Wright, Haviland	1 00
C. P. Ketelson, treasurer Kinsley Lumber and Grain Co., Kinsley	50 00
A. D. Smith, cashier Bison State Bank, contributions of Bison farmers	4 00
W. M. Reckeway, Wetmore	1 00
E. J. Nason, Stockton	1 00

Contributions—*continued:*		
Buhler Mill and Elevator Co., Buhler		$2 50
C. A. King, Healy		1 00
J. W. Robison, El Dorado		5 00
W. A. Eppler, Ellis, contributions from farmers		5 00
J. M. Quiggle, Le Roy		1 00
Chas. Browning, Turon		1 00
James A. Hedrick, Gardner		1 00
Farmers Grain, Fuel and Live Stock Co., Pawnee Rock		1 00
O. E. Winkler, Paxico		2 00
W. O. Bourne, Scott City		5 00
Citizens of Utica:		
A. L. Young	$1 00	
S. M. Atwell	1 00	
J. E. Atwood	1 00	
C. E. Nuttle	1 00	
L. M. Chase	1 00	
T. O. Davis	1 00	
Roy Babcock	1 00	
A. B. Beattie	1 00	
C. M. Askew	2 00	
O. L. Peters	1 00	
Jerry Coryell	1 00	
Sol Clodfelter	1 00	
Lorin Ferrell	1 00	
C. D. Brown	1 00	
Stanford Clodfelter	1 00	
Tilman Peters	1 00	
F. M. Lovitt	1 00	
Albert Lovitt	1 00	
M. A. Chamberlain	1 00	
Alva Babcock	1 00	
A. B. Cooper	1 00	
Geo. Brown	1 00	
John T. Smith	1 00	
R. W. Jennings	1 00	
C. E. Barr	1 00	
John Pausch	1 00	
W. E. Trayor	1 00	
E. E. Turner	1 00	
B. M. Bovard	1 00	
Robert McClintock	1 00	
Pepper & Fink	1 00	
Arthur Wilson	1 00	
W. V. Elting	1 00	
		34 00
Citizens of Palmer:		
W. C. Brown	$2 00	
Bank of Palmer	1 00	
Bert Hartnett	2 00	
P. T. Thompson	1 00	
C. E. Myer	1 00	
Palmer & Slipsuger	1 00	
D. C. Megasson	1 00	
Wm. Farnsworth	25	
Pete Shoemaker	1 00	
O. A. Fowler	1 00	
		11 25
J. F. Russell, Colony		1 00
T. P. Kitner, Lewis		1 00
D. D. Denver, agent, Milford		1 00
G. Zorn, Centerville		1 00

Contributions—*continued:*		
W. E. Traylor, cashier Citizens State Bank, Utica	$7 00	
J. C. M. Anderson, Brownell	2 50	
I. Markley, Bennington	5 00	
J. H. Tuel, Paola	1 25	
T. G. Kennedy, Junction City	2 00	
Plainville Mill and Elevator Co., Plainville	5 00	
O. W. Jackson, Tecumseh	1 00	
Chas. M. Woodell, Nickerson	7 50	
C. F. Lambert, Leavenworth	3 00	
F. W. Banner, Clifton	1 00	
I. A. Daniels, Topeka	1 00	
Dickie & Brown, Asherville, contributions from six six farmers	6 00	
C. H. Beardslee, Ness City	1 00	
Mrs. S. Murray, Hoisington	1 00	
J. F. Boyle, Olmitz	4 00	
O. W. Davis, Shields	1 00	
J. A. Franz, Rozel	2 00	
Ridgway Bros., Paola	1 00	
D. F. Kuns, cashier Farmers and Merchants Bank, McPherson	2 00	
Ford Mason, Scott City	4 00	
Marquette Roller Mills	5 00	
Chester Thomas, Waterville	1 00	
H. V. Mahon, Burlington	1 00	
G. W. Bibens, Welda	1 00	
Frank French, Manning	2 51	
Ed. Dunham, Paola	1 00	
O. A. Hinkle, Paola	1 00	
Thos. O'Mara, Colony	1 00	
L. D. Vanderhooff, Paola	1 00	
C. J. Merrilat, Talmage	1 00	
R. A. Mann, Ada	1 00	
L. A. & G. A. Keller, Greensburg	1 00	
		$712 51
Amounts paid for parasites by Kansas counties, as follows:		
Stafford county	$202 80	
Barton county	100 00	
Kiowa county	100 00	
Gove county	50 00	
Ford county	25 50	
Reno county	50 00	
Ottawa county	15 00	
Rice county	7 50	
Douglas county	40 00	
		590 80
Postage and cash received in amounts less than $1		154 64
Received from railroad companies for unused tickets		6 12
Received from field agents, account return of expenses advanced,		39 82
Total		$2,316 39

DISBURSEMENTS.

Expenses of field assistants gathering parasites	$597 96
Railroad fares and transportation	95 03
Expenses of telephoning and telegrams	25 35
Express charges on shipments of parasites	177 18
Drayage	12 55
Barrels and boxes	113 90
Postage-stamps and post cards	149 38
Wrapping-paper, $21.12; twine, $16	37 12
Printing circulars, $28; labels, $11	39 00
Office supplies, letter-files, etc	7 70
Supplies for laboratory experiments	8 25
Labor preparing and shipping parasites	124 32
Stenographic assistance	105 20
Laboratory assistance	77 20
Funds rebated to guarantors and purchasers of parasites	746 25
Total	$2,316 39

R. C. JACKMAN,
EDW. E. BROWN,
S. J. HUNTER.
Finance Committee.

LETTERS FROM WHEAT-GROWERS.

"May 21, 1907.

"Beg to say that we do not believe that the state of Kansas, generally, fully appreciates the good work you are doing at the present time, but we think that in future years they will get to know that the work that you are doing and have done is of lasting good, not only to Kansas but to the entire country. We are glad to coöperate with you in a small degree in this work, and trust that you will have plenty of funds at your disposal for carrying on the work in the largest possible measure."—THE HIAWATHA MILLING CO., H. L. KUNCE, secretary and manager. (This firm received 200 boxes.)

"In regard to the bees: I put them into the wheat-field on April 27, one day after I discovered the green bugs were in the field. I have 142 acres of wheat on my farm near the Dutton bridge and it has had green bugs in it since April 26. During the cool weather they increased, until about May 8 they were so numerous we thought they would destroy the crop. On May 9 we found the bees increasing and also found a great many dead green bugs; the bees have continued to increase and the green bugs to decrease. On the 17th I find very few green bugs left. I feel that your work has been of very great service to the wheat-growers in Kansas. I take pleasure in thanking you for your kindness to me."—W. H. PENDLETON, Lawrence, Kan., May 18.

"The bees I ordered from you some time ago came to-day. I noticed thousands of dead green bugs sticking to the leaves in the oats-field in the same manner as those in the bunch of wheat you sent me. I did not discover but two or three bees to-day, but think there are plenty here now. Think they have come from a neighbor's field, as they ordered bees from you earlier in the season. The ground is literally white with the dead green bugs. I cannot find any more in the wheat, and think they will soon leave the oats."—E. C. LEMBACH, Erie, Kan., May 21.

"The parasites are very numerous and the green bugs are almost exterminated."—A. B. CUNNINGHAM, Adams, Kan., May 20.

"I received the bugs one week ago all right; distributed as directed. There is any amount of the bees in my wheat; eighty per cent. of the bugs have disappeared from some cause. The weather probably had something to do with them. Had a big rain yesterday, and we are in better hopes to-day."—C. M. EASTERLY, Dexter, Kan., April 30.

"I received the box of bugs you sent me and put them in the wheat at once, and am pleased with the results."—J. R. THOMPSON, Winfield, Kan., April 30.

"The parasites received the 27th, and I put them in the wheat-fields at once, and we watched them work. We noticed two of the little bees attack the green bugs in just a few minutes after they were liberated.—CHAS. W. LOWE, Galva, Kan., April 29.

"I put the parasites at once in my wheat, and I think they are commencing to work on the green bug. The last week the green bug has not been so noticeable as the week before, so I draw the conclusion that the parasites are working on them."—HARRY E. KIFF, Abilene, Kan., April 27.

"Your bug came all O. K. My boy put it out in the fields yesterday forenoon. They went for the green lice right away."—A. J. BUCKMAN, Conway, Kan., May 2.

"We have placed all the packages you sent us, twenty-four in number, with good farmers, and all the reports we have had from them have been favorable."—DICKINSON BROS., Humboldt, Kan., May 4.

"We received the two boxes of bugs you sent us and distributed the bugs in the field this morning. The field in which we put the two first boxes sent us is improving, and we find an immense number of dead bugs scattered throughout the fields, and think it is doing a great amount of good."—J. M. LANE, Burlington, Kan., May 20.

"I received the box of parasitic bees on the 12th of May, and put them in the field as you directed. The weather turned cold but has warmed up again and been very favorable for them since. We have been watching their movements very closely and consider they have done most of their work. In the 200 acres of wheat there is hardly a green bug to be seen where they were pretty thick, and in the oats and barley, where the green bugs were as thick as they could be, we now think fifty per cent. are killed."—D. N. HILL, Lyons, Kan., May 17, 1907.

"I wish to thank you for your parasites; am glad to report that the green bugs are dying by the thousands the last few days."—JOHN L. MILLER, Neosho Rapids, Kan., May 15.

"I received the box of parasites Tuesday, the 14th, and the 16th of May I found dead green bugs in my field."—G. L. MEIERDIRCKS, Marion, Kan., May 16.

"The parasite seems to be getting in its work on the green bug here now."—I. G. LAW, Milton, Kan., May 15.

"The green bugs seem to have largely disappeared here now. Two weeks ago there were millions to one in my wheat. I thank you very kindly for the bugs sent me."—A. Z. BROWN, Guilford, Kan., May 15.

"The bugs you sent me I put out in the field. Was out in the field this morning and found lots of dead green bugs sticking to the wheat."—R. M. GILBERT, Haviland, Kan., May 16.

"I write you in regard to the bugs I got of you. It is ten days since I put them in my wheat. They have increased until they are about as thick as the green bugs. I find some dead bugs. They have hurt the wheat awful bad, but if they stop within a few days I believe I will get seven or eight bushels to the acre."—WILL SLADE, Stafford, Kan., May 20.

"In regard to the parasitic bees that I asked you for and received and put out in the wheat the 10th inst., will say that I think they have done a good job, as I think the green bugs are about all dead by this time. I estimated that seventy-five per cent. of the green bugs were dead last Saturday, and the parasites were quite numerous."—J. DELL DAVIS, Langdon, Kan., May 22.

"Received the box of the bees that destroy the green bug on Friday, May 10, and distributed in my wheat-field. This morning I find the bees distributed all over my 110-acre field in large numbers and the green bugs are gradually disappearing. I thank you for sending them and think they will

go a long way toward saving my wheat crop."—FRANK RITCHIE, Abbyville, Kan., May 20.

"Wish to say that you sent E. I. Davis, of Haviland, and he placed them in a field that I have control of. I was examining the wheat there yesterday and found parasites over the entire field; only found one live green bug in the field. The parasites had been in the field eleven days yesterday."—J. N. WAYNE, Greensburg, Kan., May 20.

"The bees were received all O. K., and many thanks. There were quite a lot of the green bugs in my wheat and it was beginning to show on the wheat, and now since putting out the bees the wheat is looking fine. I have thousands of the bees now."—I. C. BARRICKLOW, Baldwin, Kan., May 20.

"The little fellows are sure putting in their time, and am very much pleased with them."—GEO. BIGSBY, Lawrence, Kan., May 12.

"I received parasites O. K., and think they are doing the wheat good."—R. E. PARTRIDGE, Greensburg, Kan., May 21.

"I received the parasites you sent me and see they are working on the green bugs."—J. B. DONOHOE, Shields, Kan., May 22.

"Found a great many parasites already in the wheat, and they certainly do the work with the green bugs. Could see their work very plainly on the wheat from the number of dead green bugs."—JOHN GARVIN, Stafford, Kan., May 23.

"Received the box of parasites the 10th; they are all over the field now. I believe if we could have had the bees about a month ago the green bugs could not have done much damage."—PAUL KRUG, Hudson, Kan., May 23, 1907.

"I received your two boxes of the parasites and have distributed them in the wheat- and oat-fields. Most of the green bugs have left the wheat-fields, as the wheat is about to the heading-out stage, and they also have largely left the oat-fields."—

"I have scattered the parasites about in the field. I do not need to wait for the results, for I know now what they will be. Two or three days before the parasites came other parasites which you had sent to one of my neighbors began coming from his field into mine. The results were exactly what you stated they would be. Brown and black dead bodies of the green bugs could be found sticking to the blades of the wheat plants wherever the parasites had gone. At the present time nothing but the frame of the body of the green bug can be found. I have found by examining these frames closely that there is a small hole on the back, showing that from that body a new generation of parasites has made its exit. Nevertheless, I scattered the parasites that you sent me about in the wheat-field to assist the other parasites and to make the destruction of the green bug complete. I am thoroughly convinced that the parasites are doing everything claimed for them, and believe that if the farmers of this particular locality had sent for parasites when the green bug first made its appearance the destruction wrought by the green bug would have been reduced to a very small per cent."—PETER YOUNG, Iola, Kan., May 26, 1907.

"The parasites you sent me received in good shape and distributed in the field as you directed. I sent a little too late, as the green bugs had

begun to die pretty fast. Since I saw the parasite and found out what they looked like, I found them already in the wheat. Several of the neighbors had sent for parasites and I think they came from other fields. I feel sure that there has been great good done by your effort to exterminate the green bugs."—W. C. WYMAN, Langdon, Kan., May 27.

"I received the parasites all right. The bugs have all been dead for several days and there is no doubt that you are doing a great work in your department."—JAMES DOUGLAS, Emporia, Kan., May 27. (Parasites were sent to Mr. Douglas May 8.)

"Sometime since I wrote you, wishing you to send me some of your parasites to exterminate the green bug. They arrived in due time and we distributed them among the growing oats. We were out looking after the results this morning. There appears to be a very few live green bugs and any amount of dead, so I think the ones you have sent are having the desired effect."—J. B. JONES, Sedgwick, Kan., May 25.

"I received the parasites all right two weeks ago and within one week they were over my entire wheat-field of sixty-five acres. Now there are but very few green bugs left."—C. W. NORMAN, White City, Kan., May 25.

"On your request of how those parasites have done their work I must say the result was good. I put them into my oats and they increased very rapidly. I could find only a few green bugs yesterday. The oats are growing nicely now, so I can say the parasites have done the work all right. Many thanks to you."—PETER BACHMANN, Halstead, Kan., May 26.

"Received the bugs you sent me in good shape. Our fields are practically rid of the 'green bugs' by this time and would not have needed any parasites, but nevertheless I am very grateful to you for the work you have done, for I am satisfied that this parasite that you have distributed all over the state has done the work. To my judgment it took just about three weeks after the parasite came in to rid the pest."—J. A. SCHOWALTER, Halstead, Kan., May 26. (Parasites were distributed near Halstead, Harvey county, the last of April and the early and middle part of May.)

"I received the box of parasites and scattered them through the wheat. There is not a green bug in sight now. They saved the wheat; I think it will make half a crop now. The oats was all gone before I got the parasites. The corn looks fine. No green bugs."—JAS. W. TYSON, Anthony, Kan., May 25, 1907. (Parasites sent May 13.)

"The parasitic bees sent me arrived one week ago. Were distributed at once. Yesterday was examining my crops. There are thousands of the bees."—FORD L. PERKINS, Galva, Kan., May 27.

"I received the box of bees all O. K. I was out in the wheat to-day. I find plenty of dead bugs on the wheat. I think there is anyway twenty per cent. of them dead. I wish you would send me two or three boxes more to scatter in some wheat I have in Reno county."—F. M. HOUSTON, Sterling, Kan., May 15. (Bees sent April 25.)

"Parasites arrived all O. K. I was in the field forty-eight hours after the parasites were distributed and found quite a number of green bugs turning brown. As the field is over two miles from home I have not been able to visit it since on account of rush in replanting corn. I have visited an oats field a few days ago where I found quite a number of black dead bodies, and

living parasites also. This field was about a mile from where parasites had been distributed, which seems to indicate that the parasites are naturally traveling north with the wheat-louse."—H. C. COESTER, Walnut, Kan., May 25, 1907.

"Received the parasites May 9. Put them in the field, and on May 12 looked at them and they were doing good work."—WM. GORDON, Lecompton, Kan., May 15.

"The parasites have created great havoc among the green bugs. I think there is not a live bug to be found in the neighborhood."—JOHN SCHOENHOFER, St. Paul, Kan., May 24.

"I have received your second shipment of parasites, and you need not send any more, as I have all I need now. The bugs are dying fast and I don't think they will damage us much more."—D. F. KUNS, president Farmers and Merchants Bank, McPherson, Kan., May 25.

"I received your parasites for the green bug and put them in the fields a few days ago. I was examining my oat-field and find that there were lots of dead bugs."—G. D. CATLIN, Sharon, Kan., May 27.

"We are very thankful for the parasite bees. They have exterminated the green bug on our farm beyond a doubt."—J. W. PELPHREY, Humboldt, Kan., May 28.

"I will drop you a line in regard to your parasites. I can hardly say enough of their good work. The green bug had principally left my fall wheat and gone on spring wheat. By the time I received your box they had covered the spring wheat, but now it is hard to find a live green bug. I am satisfied the box you sent me made me several dollars on my wheat crop, for they would have taken all the spring wheat if they had n't been stopped."—I. H. L. SNYDER, Bayard, Kan., May 30.

Prof. P. A. Glenn, acting head of Department of Entomology, University of Missouri, on May 29 drove fourteen miles east from Wa Keeney, Kan., examining every wheat-field, and reports finding green bugs in every field, but parasites in but two fields—the one for which parasites were sent from the University and the field adjoining on the north. Parasites had mastery of the situation.

"The parasites that you sent me have got in their work. I examined my wheat and barley to-day, and could find only a very few green bugs where there were thousands a week ago "—E. B. DAY, Bellefont, Kan., May 31.

"Five days after we distributed the parasites there were many dead bugs in the fields. I examined many of them and found in the body of each a young parasite. The green bugs are about all gone. About eight or ten days ago the parasites were flying in the air almost as thick as the green bugs had been. Your work has surely been a great success."—A. H. COUCH. professor of biology, Cooper College, Sterling, Kan., May 31.

"The parasites were received over a week ago and were scattered according to directions, and they went to work right away. Eight days after I turned them out I found only two live green bugs. In a few days the parasites were in all the neighboring fields. I believe that the amount saved through your instrumentality would pay all of the Kansas taxes for 1907."—WM. DANNIFER, Cuba, Kan., June 1.

"On examining my oat-field, in which the green bug parasite was distributed one week ago, I find dried bugs adhering to the leaves of the oats but no green bugs."—F. R. RUSSELL, McCune, Kan., May 31.

"We received the parasites for green bugs all O. K., for which we thank you. They have cleared our place, also adjoining places, of the green bugs."—CHAS. W. ZABEL, Marion, Kan., May 30.

"I have received parasites and they have proved very satisfactory."—C. G. RUSTED, Lawrence, Kan., May 27.

"You sent a box of parasites two weeks ago to-day. I distributed them in a badly infested wheat-field and could begin to find dead green bugs in two days. Now it is almost impossible to find a green bug. Your discovery is a great thing and worth thousands to the farmers of Kansas."—A. A. HICKS, Lawrence, Kan., May 10.

"Will you please send me one box of your green bugs? My neighbor, Mr. Speaks, received a box from you and he claims they are doing the work nicely."—LEE DUGAN, Macksville, Kan., May 3.

"We are certain that we can see traces of the parasite working in our fields here. The distribution, however, has been so small that of course the green bugs are still doing quite a bit of damage. If you can do so kindly send us another box of the bees."—THE C. HOFFMAN & SON MILLING CO., Enterprise, Kan., May 18.

"I received a box with green bug killers May 23 and distributed them the same day in my oat-field. After about five days I noticed quite a number of small winged ants and about half the number of green bugs. At present the bugs seem to be all gone or dead."—F. N. FUNK, Canada, Kan., June 6.

"Received bugs some time ago. About ten days after I scattered them I noticed hundreds of brown bugs on the wheat. . . . There are no bugs of any kind now, and wheat is looking very fine except where frosted."—C. S. WALKER, Macksville, Kan., June 14, 1907.

"Enclosed find twenty cents in stamps to cover postage on parasites. The parasites have about destroyed the green bugs here, and wheat is so far advanced that they will do no further damage. The Department of Entomology should be praised for the excellent work they have done toward the destruction of this pest."—CLINTON W. GAMBEE, Tweed, Kan., June 15.

"The parasites sent by you were received in due time, and will say they did the work intended. I cannot find a green bug or parasite either."—M. F. BELL, Olmitz, Kan., June 19.

"You wanted a report on the parasites. I find no green bugs, and black and brown spots on the wheat and oats blades, and can say that they saved my grain. I thank you very much for them."—C. M. HUSTEN, Paola, Kan., June 19.

"I have never sent you a report yet from those parasites. I have this to say for them: I know that if it had not been for the bees I would not have had any wheat and oats. I think that they did a great deal of good for me."—L. M. FRENCH, Weir, Kan., July 14, 1907.

"I was one of the first to secure a box of your parasites through the county clerk (Lang) of Reno county in my neigborhood. I received benefit

therefrom, as the green bug was entirely gotten rid of."—W. W. HAMILTON, Nickerson, June 29.

"When you sent me the bees to kill the green bug you sent a request that I report to you the result of the work. I placed some on the wheat, some on the oats, and in a week's time you could not find a single green bug, and I have an army of bees now. . . . If I had sent three weeks sooner I could have saved the entire crop."—C. W. RADTKE, Valley Center, July 8. (Sent May 13.)

"Parasite bees were received from you on June 4, and that day and the following day I distributed them in the green-bug infested spots in my oat-fields. Some spots were heavily infested with green bugs, especially next to my young corn. I feared more for the corn than the oats, so I watched closely for results. In five days I found some dead green bugs sticking to grain stalks and quite a number getting dark in color but still at work. Ten days after but few green bugs could be found alive, but parasites were getting numerous. Now, one month since getting them, I find parasites in the oats, corn and potatoes, but am unable to find a single green bug."—A. J. WHITE, Effingham, Kan., July 3, 1907.

BIBLIOGRAPHY.

The following authors are referred to in this report:

DEL GUERCIO, G.
1906. Estrallo dul Bolleltino ufficial del Ministuero di Agricultura Industria e Commercio, pp. 12, 13.

FERNALD, H. T.
1908. Future of Economic Entomology. Pop. Sci. Mo., vol. 72, pp. 174–178.

HOUSE OF REPRESENTATIVES, U. S.
1908. Hearings before Committee on Agriculture.

HOWARD, L. O.
1897. A Study in Insect Parasitism. U. S. Dept. Agr. Bureau of Entomology Bull. No. 57. Tech. Ser.

HUNTER, S. J.
1908. Experiments and Knowledge of the Green Bug, *Toxoptera graminum*, to date. Report of Kan. St. Bd. of Agr., vol. XXVII, pp. 35–54.

HUNTER, W. D.
1908. Studies of Parasites of the Cotton Boll Weevil. U. S. Dept. Agr. Bureau of Ent. Bull. No. 73.

MARCHAL, PROF. PAUL.
1908, April. The Utilization of Auxiliary Entomophagous Insects in the Struggle against Insects Injurious to Agriculture. Pop. Sci. Mo., vol. 72, No. 4.

1908, May. The Utilization of Auxiliary Entomophagous Insects in the Struggle against Insects Injurious to Agriculture. Pop. Sci. Mo., vol. 72, No. 5.

MORGAN, T. H.
1907. Experimental Zoölogy, pp. 323–335.

PASSERINI, DR. J.
1863. Aphididæ Italiæ, Genoa, pp. 28, 29.

PERGANDE, THEO.
1902. Bureau of Ent. U. S. D. A. Bull. 38, N. S.
1904. Bureau of Ent. U. S. D. A. Bull. 44, pp. 5, 14.

PIERCE, W. D.
1908. Studies of Parasites of the Cotton Boll Weevil. U. S. Dept. Agr. Bureau of Ent. Bull. No. 73.

REPORTS OF THE U. S. WEATHER BUREAU.
1884–1909. Both national and sectional.

RODANDI, DR. C.
1852. Nuovi Ann. della Science. Series III, vol. VI.

STEVENS, N. M.
1906. Studies in the Germ-cells of Aphids. Carnegie Institution, Washington, D. C.

TANNREUTHER, GEO. W.
1907. History of the Germ Cells and Early Embryology of Certain Aphids. Zoölogischen Jahrbüchern, Band. 24, Heft 4.

WASHBURN, F. L.
1907. The so-called Green Bug and other Grain Aphids in Minnesota in 1907. Special report to governor.

WEBSTER, F. M.
1907. The Spring Grain Aphis, *Toxoptera graminum*, U. S. Dept. Agr. Bureau of Entomology, circular No. 85; March.
1907. The Spring Grain Aphis or so-called Green Bug, *Toxoptera graminum*. U. S. Dept. Agr. Bureau of Entomology, circular No. 93; August.
1907. Value of Insect Parasitism to the Farmer. Yearbook U. S. Dept. Agr., p. 255.

INDEX.